Vol. XLII JANUARY, 1923 No. 1

JOURNAL OF THE American Institute of Electrical Engineers

PUBLISHED BY THE INSTITUTE
33 WEST 39TH ST • NEW YORK CITY

American Institute of Electrical Engineers

COMING MEETINGS

Midwinter Convention, New York, February 14-16

Spring Convention, Pittsburgh, April

Annual Convention, Swampscott, Mass., June, 25-29

Pacific Coast Convention, San Francisco, September

MEETINGS OF OTHER SOCIETIES

American Institute of Mining and Metallurgical Engineers, Annual Meeting, New York, February, 19-21

American Society of Civil Engineers, New York, January, 17-18

Society of Automotive Engineers, Annual Meeting, New York, January, 9-12

JOURNAL

OF THE

American Institute of Electrical Engineers

PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 West 39th Street, New York

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Philippines; $10.50 to Canada and $11.00 to all other Countries. Single copies $1.00.

Entered as matter of the second class at the Post Office, New York, N. Y., May 10, 1905, under the Act of Congress, March 3, 1879. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized on August 3, 1918.
Printed in U. S. A.

Vol. XLII JANUARY, 1923 Number 1

TABLE OF CONTENTS

Papers, Discussions, Reports, Etc.

Institute and Related Activities

Current Articles Published by Other Electrical Societies

American Electrochemical Society

The Effect of Single Impurities on the Electrodeposition of Zinc from Sulphate Solutions, by John T. Ellsworth, Park City, Utah.

The Proportion and the Mechanical Properties of Vacuum-Fused Alloys of Electrolytic Iron with Carbon and Manganese, by Robert P. Neville and John R. Cain of The Bureau of Standards.

Electric Heat, Its Generation, Propagation and Application to Industrial Processes, by E. F. Collins, General Electric Co.

Proceedings of the Institute of Radio Engineers, Oct., 1922.

The Dynatron Detector, by Albert W. Hull, E. F. Hennelly and F. R. Elder.

Application to Radio of Wire Transmission Engineering, by Lloyd Espenschied, Am. Tel. & Tel. Co.

A Method for Testing and Rating Electron Tube Generators, by L. M. Hull, Bureau of Standards.

Mathematical Treatment of Rectification Phenomena, by D. C. Prince, General Elec. Co.

Transactions of the Illuminating Engineering Society, December, 1922.

Overcoming Daylight Reflections in Show Windows, by Ward Harrison and H. T. Spaulding.

Effect of Light on the Drawing Power of the Show Window, by Walter Sturrock and J. M. Shute.

Tentative Code of Luminaire Design, by Committee to Cooperate with Fixture Manufacturers.

Association of Iron and Steel Electrical Engineers, December, 1922.

Improved Rolling Mill Practise Obtained by the Use of Direct-Current Motors for Main Roll Drive, by G. E. Stoltz.

Safety Switches, by P. T. Vanderwaart.

Journal of the American Welding Society, December, 1922.

Welding as a Factor in Steel Plant Maintenance, by E. R. Norris.

Telephone Transmission Over Long Cable Circuits

BY ALVA B. CLARK
Member, A. I. E. E.
American Telephone & Telegraph Co.

Review of the Subject.—*The application of telephone repeaters has made it possible to use small gage cable circuits to handle long distance telephone service over distances up to and exceeding 1000 miles. A general picture of the long toll cable system which is being projected for use in the northeastern section of the United States was presented recently by Mr. Pilliod before this Institute.**

Many of the circuits in these toll cables are so long electrically that a number of effects, which are comparatively unimportant in ordinary telephone circuits, become of large and sometimes controlling importance. For example, the time required for voice energy to traverse the circuits becomes very appreciable so that reflections of the energy may produce "echo" effects very similar to echoes of sound. The behavior of the circuits under transient impulses, even when two-way operation is not involved so that "echoes" are not experienced, is very important. In order to keep within proper limits of variation of efficiency with frequency over the telephone range special corrective measures are necessary. Owing to the small sizes of the conductors, the attenuations in the longer circuits are very large. Special methods are, therefore, required to maintain the necessary stability of the transmission, including automatic means for adjustment of the repeater gains to compensate for changes in the resistance of the conductors caused by temperature changes.

*JOURNAL of the A. I. E. E. Vol. XLI, 1922, August, p. 585.

CONTENTS

THIS paper aims to present an idea of what is involved in the transmission of voice currents over long toll cable circuits. Because of the breadth of the subject covered, no attempt has been made to make the discussions of the various items complete, or to include many of the results of the experimental and theoretical work which contributed to a solution of the problems and which has involved the cooperative efforts of a large number of engineers and investigators. This paper should be considered merely as an introduction to the subject. It is hoped that subsequent papers will be presented dealing with these matters in more detail.

For the benefit of those who are not intimately in touch with telephone transmission work, the different types of circuits used in toll cables are first briefly reviewed. The important characteristics of the loading systems are then presented. Following this, various important effects encountered in long cable circuits are discussed and their reactions on the design of cable systems indicated.

In view of the discussion on telephone repeaters given in the Gherardi-Jewett paper,[1] which was presented before this Institute on October 1, 1919, it will be assumed that the reader of the present paper is familiar with the general features possessed by the various types of such devices and, accordingly, no descriptions of them are given, their over-all performance only being of interest in the present connection.

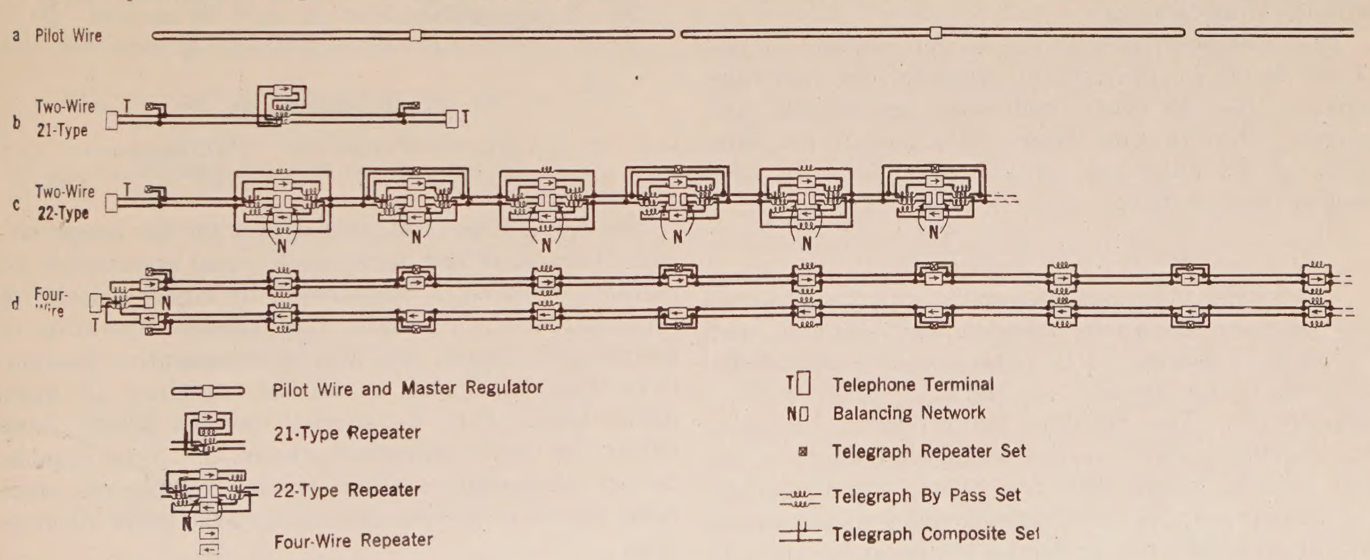


FIG. 1—DIFFERENT TYPES OF CABLE CIRCUITS

DIFFERENT TYPES OF CIRCUITS

The different types of circuits used in toll cables are illustrated in diagrammatic form in Figure 1. Circuit "b" is a two-wire telephone circuit employing a 21-type telephone repeater. This type of circuit is employed

To be presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 14-17, 1923.

1. TRANSACTIONS of A. I. E. E., Vol. XXXVIII, Part II, p. 1287.

only for handling connections on which but one telephone repeater is involved. Circuit "*c*" is a typical two-wire circuit on which the familiar 22-type telephone repeaters are operated. Circuit "*d*" is of the four-wire type which employs two transmission paths, one for each direction. The function of the pilot wire circuits, "*a*", will be taken up later.

With the exception of circuit "*b*", which possesses the limitation that it cannot advantageously be connected to another circuit containing telephone repeaters, the circuits shown in the figure may be connected, when required, to circuits of the same or other types, such as open-wire circuits, to build up various telephone connections. In general, circuits such as "*c*," employing 22-type repeaters, are used for handling connections of moderate lengths, while circuits such as "*d*" of the four-wire type, are employed for the longer connections where the transmission requirements are more severe.

In addition to employing the cable conductors for furnishing telephone service, these may also be arranged to furnish d-c. telegraph service. Apparatus for compositing the circuits so as to permit this superposition of the d-c. telegraph is indicated on the drawing. In general, the method of compositing the small gage cable circuits is the same as that employed for compositing open-wire lines. The telegraph circuits in cable, however, operate with a metallic instead of a grounded return and employ much weaker currents than those common on open wires. Telegraph currents employed in the cables are comparable in magnitude with the voice currents.

The two-wire circuits in toll cables employ conductors of No. 19 or No. 16 A. W. G. while for the four-wire circuits, No. 19 wire conductors are usually employed. (No. 19 wire weighs 20½ pounds per wire mile, or 5.8 kilograms per kilometer. No. 16 wire weighs twice as much).

Loading Characteristics

Two weights of loading are usually employed. These are commonly known as "medium heavy loading" and "extra light loading" and in this paper they will be referred to for brevity as "m. h. l." and "x. l. l." respectively. The medium heavy loading employs coils having an inductance of about 0.175 henry in the side circuits, spaced 6000 feet apart, (approximately 1.8 kilometers); the extra light loading employs coils having an inductance of about 0.044 henry for the side circuits with the same spacing. The capacity per loading section for the side circuits is approximately 0.074 microfarad.

The medium heavy loaded side circuits have a characteristic impedance of about 1600 ohms, and a cut-off frequency of about 2800 cycles. The extra light loaded side circuits have an impedance of about 800 ohms and a cut-off frequency of about 5600 cycles.

Fig. 2 shows the attenuation-frequency characteristics of No. 19 and No. 16 side circuits with the two types of loading. It will be observed that the m. h. l. circuits have lower attenuation for frequencies below about 2500 cycles, as should be expected from the fact that the inductance per mile introduced by the loading coils is greater. However, the attenuation is more nearly equal at different frequencies in the case of the x. l. l. circuits, this being particularly true at the higher voice frequencies.

Another important characteristic of loaded circuits when repeaters are involved is their velocity of propagation. Since the inductance per mile of x. l. l. circuits is only ¼ of that for m. h. l. circuits, the velocity of propagation is twice as great for the x. l. l. circuits as indicated by the well-known approximate formula

$$V = (L\,C)^{-\frac{1}{2}}$$

Where V is the velocity in unit lengths per second, L is the inductance in henries per unit length and C is the capacity in farads per unit length, the unit of length for expressing velocity, inductance and capacity being the same.

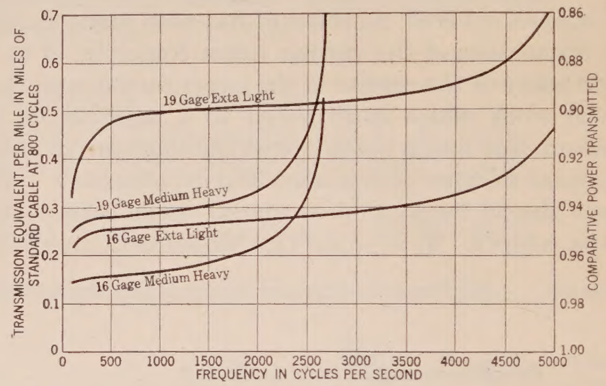


Fig. 2—Attenuation-Frequency Characteristics of Loaded Cable Side Circuits

The x. l. l. type of loading is best for the longer circuits, because of the more nearly equal attenuation of currents of different frequencies, its higher velocity of propagation which permits more efficient operation of telephone repeaters, and also its comparative freedom from transient effects, as will be explained in more detail later. For the shorter circuits where these effects are not so important, the m. h. l. type is satisfactory electrically and is therefore employed, since fewer repeaters are required owing to the lower attenuation.

"Echoes"

As is well known, whenever points of discontinuity or unbalance occur in a telephone circuit, reflections of electrical energy take place. If the circuit is long so that the time for transmission is appreciable and if also the losses are not so great as to cause the reflected energy to become inappreciably small before it reaches the ear of a listener, echo effects will be experienced. While, in general, reflections take place in any telephone circuit actual echoes are never appreciable unless tele-

phone repeaters are employed. In the case of circuits with repeaters, the electrical length is usually great enough so that an appreciable length of time is required for the voice currents to travel to some discontinuity and back again. Furthermore, the repeater gains keep the reflected voice currents large.

It should be understood that the echo effects which are experienced in long repeatered circuits are due to the same unbalances, which, on shorter circuits, bring in trouble due to "singing," or distortion of the voice waves due to "near-singing." On electrically long circuits, due to the comparatively great time lags involved, the echo effects become of controlling importance. Consequently, it is, in general, necessary on such circuits to work the repeaters at gains well below those at which "singing" or distortion due to "near-singing" is experienced.

The echo effects which occur in four-wire circuits will first be discussed, since the effects are simpler in this case than they are in the case of a two-wire circuit.

Fig. 3a shows a four-wire circuit in diagrammatic form, while Fig. 3b shows the echoes which are caused by the unbalances at the terminals. When someone at terminal A talks to a person at terminal B, the heavy line in Fig. 3b shows the direct transmission, which takes place over the top pair of wires in Fig. 3a. When this current reaches the distant terminal, part of it goes to the listener while another part, due to the imperfections of balance between the line and network at that terminal, travels back through the pair of wires at the bottom of Fig. 3a toward terminal A. The talker at terminal A will hear this current as an echo if

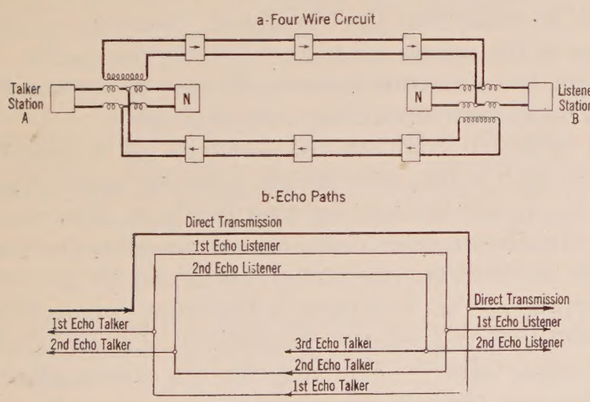


Fig. 3—Echo Paths in Four-Wire Circuit

the four-wire circuit is long enough so that the time lag is appreciable. This first echo heard by the talker divides at terminal A in the same way as did the direct transmission at terminal B, part of it taking the upper path of Fig. 3a back toward the listener. The listener will, therefore, first receive the direct transmission and then a little later an echo. This process is repeated producing successive echoes which are received at both terminals A and B as indicated.

A four-wire circuit 1000 miles (1600 kilometers) long has been set up in which the balances at the two ends were deliberately made poor so as to exaggerate the effects. More than a dozen successive echoes could be heard before they became inaudible. Since for each echo the voice energy traveled 2000 miles (3200 kilometers) this energy must have travelled the distance around the world before becoming inaudible.

In order that a circuit will be satisfactory for regular telephone use, the echoes must be kept small as compared to the direct transmission. Evidently if the first echoes are small as compared to the direct transmission, the later echoes will be much smaller in magnitude. For example, if the power in the first echo,

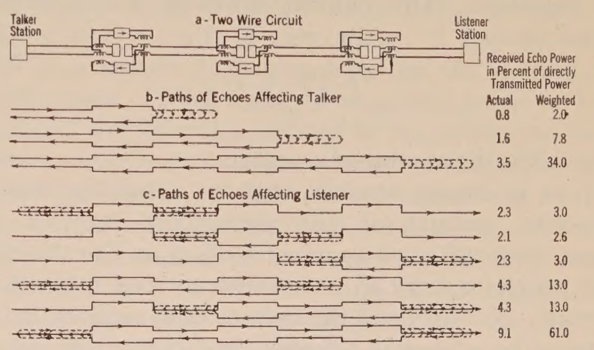


Fig. 4—Echo Paths in Two-Wire Repeatered Circuit

heard by the listener, is 1/10 as great as the directly transmitted power, the second echo will have only 1/100 as much power, the third echo 1/1000, etc.

The velocity of an x. l. l. circuit is approximately 20,000 miles (32,000 kilometers) per second, while the velocity with m. h. l. is only 10,000 miles (16,000 kilometers) per second. It is thus seen that the time required for voice energy to travel from one end to the other of an x. l. l. circuit 1000 miles (1600 kilometers) long is 0.05 second. An echo traveling from one end of the circuit to the other and back again would, therefore, arrive 0.1 second behind the impulse which started the echo. With m. h. l. circuits these times are of course doubled.

Fig. 4 illustrates the condition existing in a two-wire circuit. For simplicity, the first echoes only are shown, the later echoes being less important owing to their comparative weakness as explained above. In such a circuit reflections occur not only at the terminals, but at a number of intermediate points in the circuit, the condition of balance between the networks associated with the telephone repeaters and the corresponding lines being necessarily imperfect. This imperfection of balance is due in part to lack of perfect balance of the apparatus closely associated with the repeater, and in part to the small irregularities which exist in the make-up of any practical loaded line. A further cause is the reflection at the adjacent repeaters, due to the difference between the repeater impedance and the line impedance.

It will be noted that three sets of echoes are shown which affect the "talker." In addition to these which involve one or more repeaters, a comparatively small

amount of power is reflected back to the "talker" from the various irregularities between the "talker" station and the nearest repeater. These reflections have not been indicated since their effects are of negligible importance. Six sets of echoes affect the "listener." Both for the echoes affecting the "talker" and the "listener," the dotted lines indicate reflections from a number of different points where irregularities exist as explained above.

In circuits containing a larger number of repeaters the numbers of sets of echoes affecting the talker and listener are, or course, greater. The number of sets of first echoes affecting the talker is equal to the number of repeaters. The number affecting the listener is equal to

$$\frac{N\ (N + 1)}{2}$$

where N is the number of repeaters.

It is, of course, obvious, that for either four-wire or two-wire circuits, if the circulating energies are large, they will have an adverse effect on the ability of two people to carry on a conversation over a telephone circuit. Not only will the transmission received by the listener be adversely affected, but the talker will be considerably distracted, particularly when the time of the transmission over the circuit is so long that he hears a distinct echo of his words.

Experiments have shown that the effects of the echoes both on the listener and talker become more serious as their time lag is increased. This means that as telephone circuits are made longer it is necessary either to improve balances or to design the telephone circuits so that the velocity of propagation will be

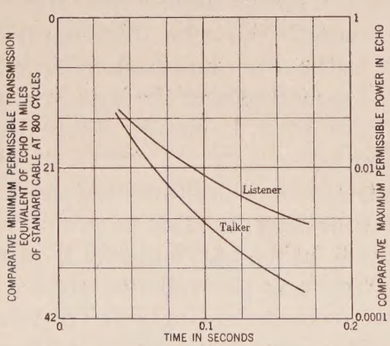


Fig. 5—Effect of Echoes on Talker and Listener

higher. This necessity for making the velocity of propagation high on long circuits was one of the principal reasons which led to the selection of extra light loading for the longer circuits.

Fig. 5 shows very approximately how the effects of the echoes vary with the length of time by which they are delayed. One curve is given for the effect on the "talker," another for the effect on the "listener." Both curves indicate, for various time lags, the comparative magnitudes of echoes which are small enough to be inappreciable when ordinary telephone conversations are carried on. The curve applying to the "listener" is referred to the direct power which he receives, while the curve for the "talker" is referred to the power which he puts into the circuit.

In Fig. 4 showing the condition existing in a two-wire circuit, the comparative magnitudes of the power in each echo are indicated, a typical condition of the lines being assumed. For the listener the echo power is expressed as a percentage of the directly transmitted

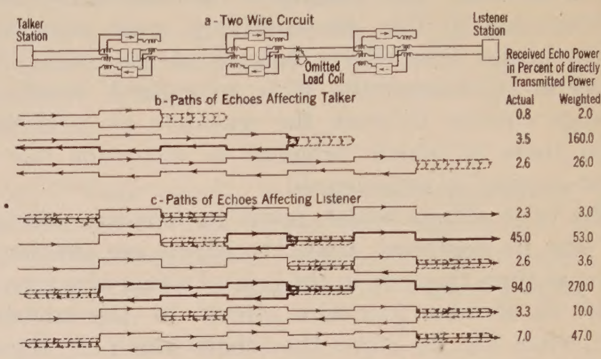


Fig. 6—Echo Paths in Two-Wire Repeatered Circuit with Omitted Loading Coil

power which he receives. In the case of the talker, it is expressed as a percentage of the power which he puts into the circuit. In addition to the comparative amounts of power in each echo, "weighted" magnitudes are indicated. The "weighted" figures take account of the fact that the effects of a given amount of echo become more serious as the time lag is increased as indicated by the curves in Fig. 5. Referring to Fig. 4, it will be noted that the "weighted" magnitudes of the power in the echoes are largest for the long paths. In general, this condition exists in the case of the majority of long two-wire repeatered circuits in cable.

In order to compare the behavior of a four-wire circuit with a two-wire circuit, consider again Figs. 3 and 4. It will be observed that in Fig. 4, showing the two-wire circuit, there is one echo received by the talker which travels from one end of the circuit to the other. Referring to Fig. 3 showing a four-wire circuit, it will be seen that this echo corresponds to the one labelled "1st echo, talker." Similarly for the echoes affecting the listener, the echo whose path is longest in the two-wire circuit corresponds to a similar echo in the four-wire circuit. Since many additional echo paths are present in the two-wire circuit, it is evident that, other things being equal, the over-all transmission result obtainable from the two-wire circuit cannot be made as good as that obtainable from the four-wire circuit.

In a two-wire circuit it is, of course, obvious that any defect in the lines which will cause a large irregularity will result in a considerable impairment of the circuit. Fig. 6 shows the effect of omitting a loading coil at an intermediate point in a circuit, the conditions in this circuit being assumed to be the same as those in Fig. 4

with the exception of the omitted loading coil. The omitted loading coil introduces a large impedance irregularity which causes certain of the echoes to be made much greater in comparative magnitude as indicated. In order to reduce the echoes in the circuit with the omitted loading coil sufficiently to make the circuit satisfactory for telephone use, it is necessary to reduce the repeater gains. In this particular case it is necessary to lower the total gain about four miles, which increases the over-all transmission equivalent of the circuit from about 10 miles for the normal condition to about 14 miles for the condition with the omitted loading coil.

Before leaving the subject of "echoes" it is believed that it will be of interest to point out some of the important characteristics of two-way repeatered circuits which result from these effects.

1. The minimum permissible net equivalent (total loss minus total repeater gain in one direction) of a four-wire circuit of a given length depends only on the velocity of propagation and the balance conditions at the terminals of the circuit. When conditions are such that the balance conditions cannot be improved, increasing the velocity of propagation will enable a lower net equivalent to be obtained.

2. In the case of a two-wire circuit with reasonably smooth lines, the exact location of the repeaters and the gains at which individual repeaters are worked have little effect on the over-all result so far as echo effects are concerned. This follows from the fact that the echo paths from end to end of such a circuit are usually of more importance than the shorter echo paths. Evidently, moving the individual repeaters about or altering their gains has no effect on the longest paths, provided the total gain in each direction is kept constant.

3. In the case of a two-wire circuit of a given length, the velocity of propagation and smoothness of the lines are of most importance in limiting the possible net equivalent, the line attenuation being of secondary importance.

For example, in the case of the transcontinental (New York-San Francisco) open-wire line, the original circuit was loaded. (Although this paper deals particularly with repeaters on cable circuits this example was selected because it illustrates this point so well). The velocity of propagation was such that voice currents required about 0.07 second to travel from one end of the circuit to the other. The total line equivalent was equal to about 56 miles of standard cable. By applying repeaters to this circuit it was possible to obtain a working net equivalent of about 21 miles.

The unloading of the circuit increased the velocity so that the time of transmission was reduced to 0.02 second, about 0.3 of the time required when the circuit was loaded. The attenuation was increased so that the total line equivalent without repeaters was equal to about 120 miles of standard cable, a little more than twice the equivalent of the loaded circuit. By applying repeaters of an improved type to this circuit so as to keep the quality good in spite of the increased attenuation and correspondingly increased gain required, it was possible to obtain a working equivalent of only 12 miles of standard cable as compared to the original figure of 21 miles. This means that with the same amount of speech power applied at one end, the power received over the non-loaded circuit is seven times as large as that formerly received over the loaded circuit.[2]

The example of the transcontinental line, above, may well bring up the question as to why it is that cable circuits are loaded. This is done for two reasons: In the first place, it is in general cheaper to load cables than it is to make up the increased attenuation by means of more repeaters. In the second place the loading lessens the amount of distortion introduced by the cable circuits. In the case of open wire circuits, their series inductance is sufficient to keep the distortion small.

Attenuations and Correponding Amplifications—Power Levels

Owing to the fact that the weight of loading applied to the longest cable circuits is very light, the attenuation of such circuits is very great. A four-wire x. l. l. 19 gage circuit 1000 miles long has the enormous line equivalent of 500 miles of standard cable. The total power amplification applied to this circuit by the repeaters exceeds 10^{47}. This amount of amplification is more than enough to talk half way around the world at the equator using non-loaded No. 8 Birmingham wire gage open wire commonly employed for handling very long distance business (No. 8 B. w. g. copper weighs 435 pounds per wire mile, or 120 kilograms per kilometer).

In order to obtain an idea of how enormous this amplification is, assume that no repeaters were employed and an attempt were made to apply enough power at one end of the circuit to enable the normal amount of speech power to be received at the distant end. The power applied at the sending end would then have to be about 50 quadrillion times as great as the total power which it is estimated is radiated by the sun.

While the total amount of power amplification is very great, the amount of amplification put in at any one point is, of course, limited. The maximum amount of power at a repeater point is limited partly by the capacity of the vacuum tubes and partly by the power carrying capacity of the telephone circuit, including the loading coils. (By power carrying capacity is here meant the ability to carry voice waves without serious distortion.) It is also necessary to limit this power to avoid serious crosstalk into other circuits.

In addition to these limitations on the maximum power, it is necessary to insure that the power at any point in a circuit does not become too small. Otherwise the normal voice power will not be sufficiently large as compared to the power of crosstalk from other circuits. It is, furthermore, evident that the ratio of power from extraneous sources, such as parallelling telegraph circuits and power supply circuits, to the voice power should be as small as practicable in order to keep the circuits free from noise.

Fig. 7 will give an idea of how the telephone power attenuates and is amplified in a long circuit. The circuit shown is similar to those which it is proposed to employ between New York and Chicago, *i. e.*, it is a four-wire x.l.l. No. 19 wire circuit largely in aerial cable, equipped with automatic means for compensating for

2. A material improvement in the telephone quality was also effected by the unloading of the circuit.

the changes in attenuation caused by the effects of varying temperatures on the resistance of the conductors. (These automatic devices are described in a later section of this paper.) For simplicity, the power levels for transmission in one direction only are shown. The solid lines show the power levels when the temperature is a maximum so that the attenuations are greatest while the dotted lines show the levels when the temperature is a minimum and the losses are, therefore,

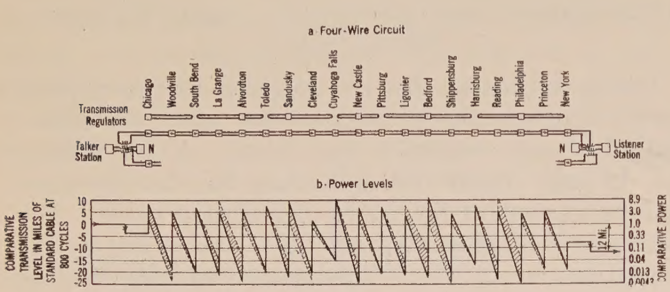


Fig. 7—Power Levels in New York-Chicago Extra Light Loaded Four-Wire Circuit

also a minimum. The shaded areas between the lines represent the changes which take place during the course of a year.

When the requirement is introduced that transmission must take place in both directions it is found that at the points in the circuits going in one direction where the power is a maximum, the power going in the opposite direction in other circuits is a minimum. This represents a very bad condition for crosstalk from one four-wire circuit into another. In order to overcome this the conductors carrying strong voice power are kept electrically separated or shielded from those carrying weak power as indicated schematically in Fig. 8. The conductors which carry strong voice power are shown heavy, while those carrying weak power are shown light. In the cable proper the separation is effected by grouping the conductors in two bunches, one for transmission in one direction, the other for transmission in the opposite direction, taking care that these two bunches of conductors are separated electrically as far as possible. In the loading coil pots the coils employed on the circuits for transmission in the two directions are similarly kept separated. In the offices the separation is effected by arranging the repeaters and other apparatus as shown in the figure. It will be observed that no special separation is shown between the repeaters transmitting in the two directions, since to keep the conductors carrying weak power separated from those carrying strong power, it is merely necessary to keep the apparatus and cabling connected to the inputs of the repeaters separated from the apparatus and the cabling connected to the repeater outputs.

Steady State Distortion

The possible sources of distortion may be divided broadly into (1) repeaters and auxiliary apparatus and (2) the lines.

With reference to the distortion introduced by the repeaters, the vacuum tube is fortunately very nearly perfect, at least in so far as concerns practical telephony. At one time, for purposes of test, a circuit was set up containing 32 vacuum tubes in tandem. On this circuit the distortion was so small that when listening to ordinary conversation it was difficult to detect any difference in the quality of transmission before and after traversing the 32 vacuum tubes.

It is beyond the limits of this paper to enter into the problems of design which were encountered in the development of the repeater circuits. For the present purpose of considering the over-all performance of repeatered circuits in cable no serious error will be made if it is assumed that the complete repeater circuits meet the requirements for an ideal repeater as set up in the Gherardi-Jewett paper.

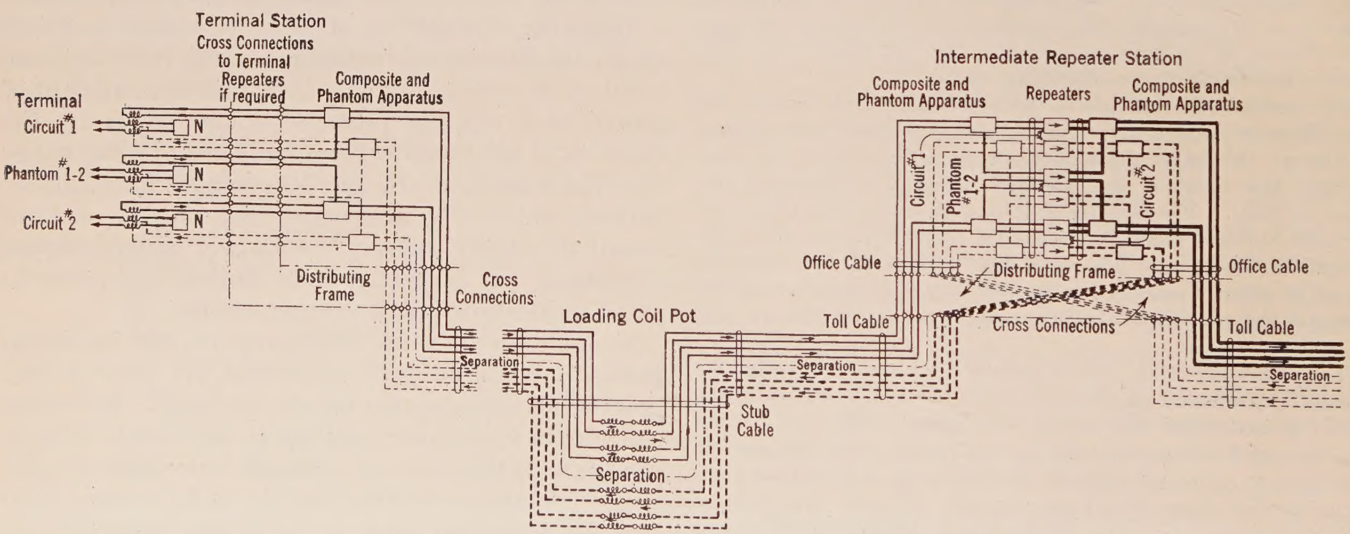


Fig. 8—Four-Wire System—Segregation Method to Reduce Cross-Talk

Considering next the lines, it is necessary to make the loading very regular so that balance difficulties will not cause an undue amount of trouble on two-wire circuits. Regularity of the loading is also essential in order to avoid irregular transmission of different frequencies. In order to secure this regularity of loading, it is necessary that the spacing between load-

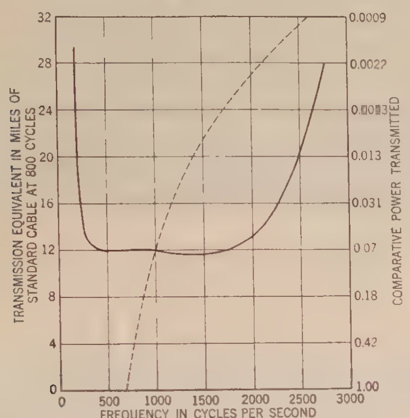


Fig. 9—Transmission-Frequency Characteristic of Long Extra Light Loaded Four-Wire Circuit

ing points be made very uniform and that the cable be manufactured so that the electrostatic capacity of its circuits be held within close limits. The loading coils themselves must be closely alike in their electrical properties and furthermore, the coils must be stable, *i. e.* these electrical properties must not change appreciably due to the passage of voice currents or other currents required for cable operation through them.

Next, it is necessary to design the repeaters and associated apparatus used on the longer circuits, particularly the four-wire circuits, so as to put in different amounts of gain at different frequencies, thereby making the over-all transmission at different frequencies approximately constant in spite of the fact that the loss introduced by the cable circuits at different frequencies is not constant. Fig. 9 shows the over-all or net transmission equivalent plotted against frequency for an x. l. l. four-wire circuit 1080 miles long (1750 kilometers) which was set up for purposes of test. The heavy line in this figure shows the over-all result which was actually obtained with repeaters and associated apparatus designed to equalize the transmission, while the dotted line shows what the characteristic would have been had the repeaters introduced exactly the same amount of gain at all frequencies.

Transients

In comparatively short telephone circuits, good quality will usually be assured if the transmission, as measured at different single frequencies within the voice range, is kept approximately constant. For electrically long circuits, however, this is not sufficient. Not only must the "echo" effects be kept within proper limits, but consideration must be given to the fact that when electrical impulses are applied to such circuits, peculiar transient phenomena are experienced. These transient phenomena occur in equal degree in two-way circuits and in circuits arranged to transmit in one direction only, that is, they are not related to "echo" effects.

In order to give an idea of the nature of some of the transient effects, some oscillograms are shown in Figs. 10, 11, 12 and 13. Fig. 10 shows an 1800-cycle current before and after traversing a cable circuit of an earlier type 1050 miles (1700 kilometers) long. This particular circuit was No. 13 A. w. g. weighing 82 pounds per wire mile (23 kilograms per kilometer) loaded with inductance coils of 0.2 henry spaced 1.4 miles (2.25 kilometers) apart and contained 6 one-way repeaters. It will be noted that the first sign of the arrival of the received

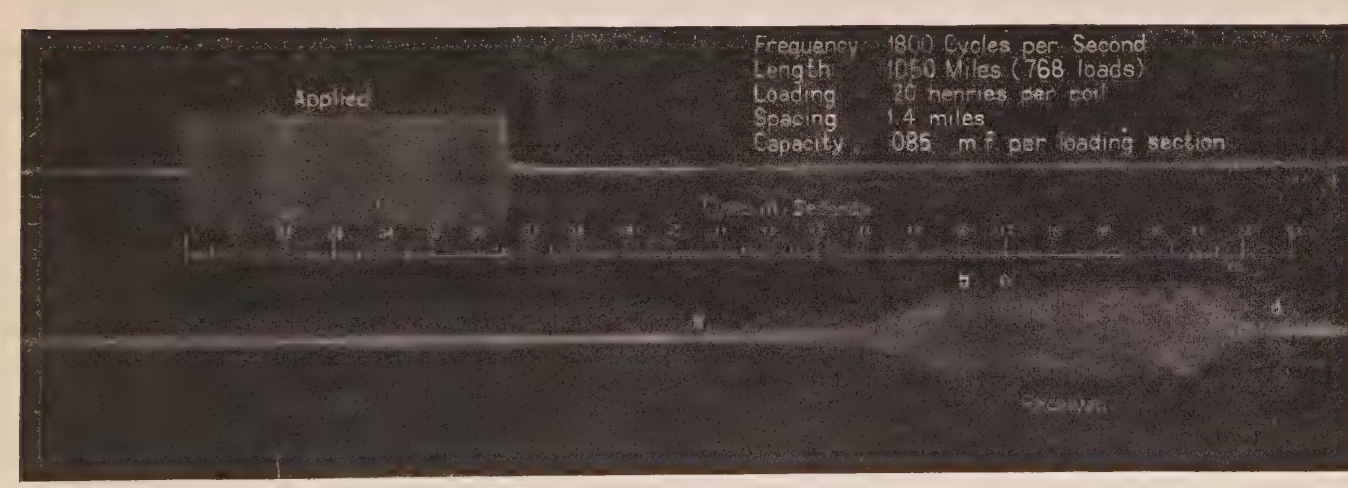


Fig. 10—Transients in No. 13 Medium Heavy Loaded Cable

current occurs about 0.1 second after the wave is put on at the sending end. This time checks with the formula for velocity given above. The time required after arrival of the first impulse (point "*a*") until the wave builds up to a practically steady-state condition at point "*b*" is about 0.055 second. The steady condition is interrupted at point "*c*" by the arrival of the break transient, the time interval between points "*b*"

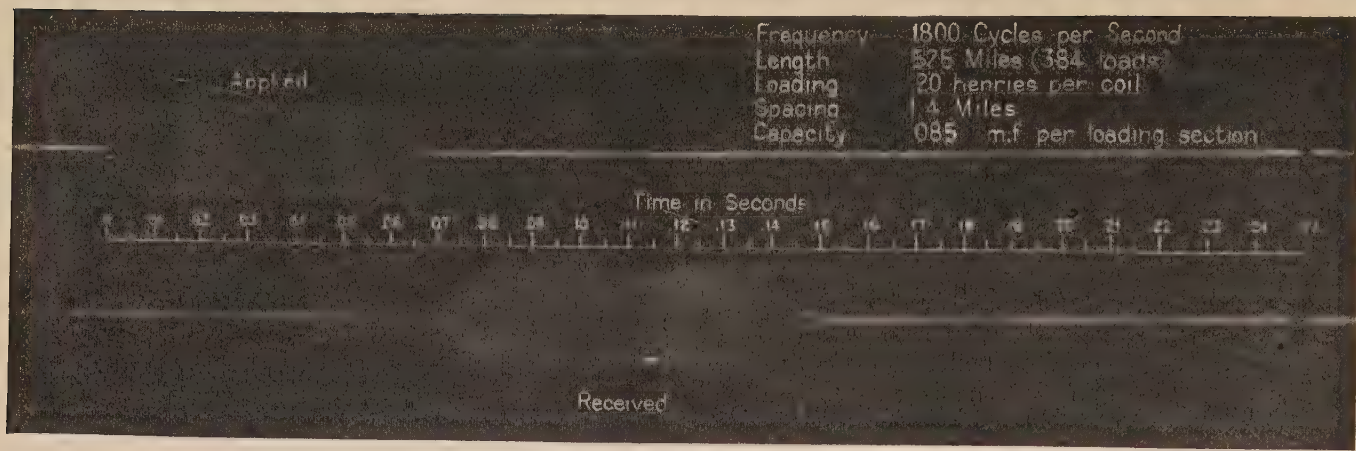


FIG. 11—TRANSIENTS IN NO. 13 MEDIUM HEAVY LOADED CABLE

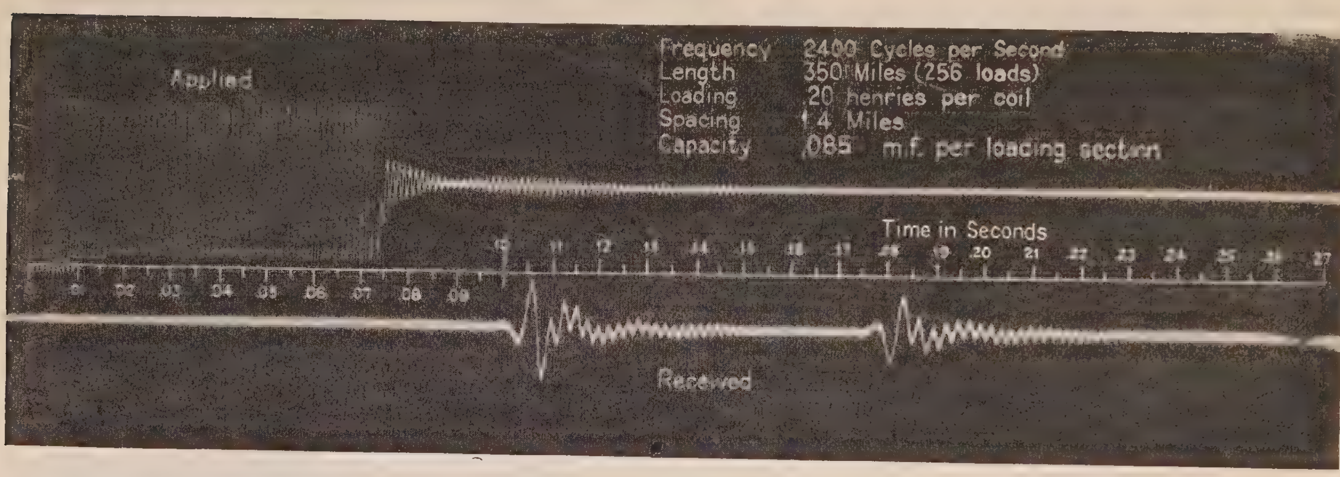


FIG. 12—TRANSIENTS IN NO. 13 MEDIUM HEAVY LOADED CABLE

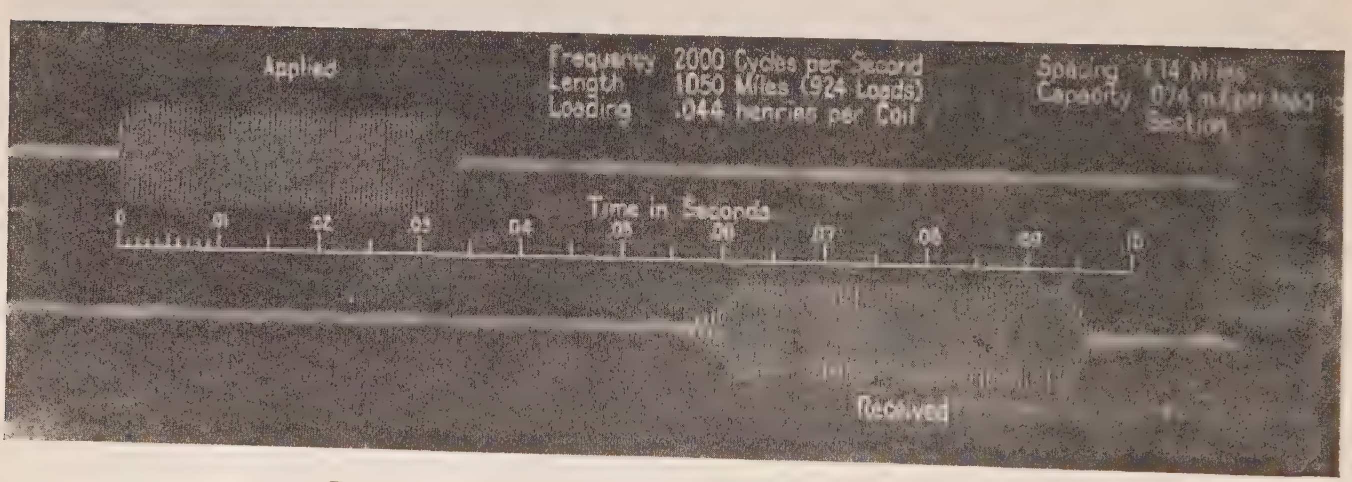


FIG. 13—TRANSIENTS IN NO. 19 EXTRA LIGHT LOADED CABLE

and "c," representing the period when the wave is in the steady-state, being only 0.01 second. The wave required about 0.055 second to die out—interval between points "c" and "d."

It is interesting to note the behavior of the current during the building-up and dying-out intervals. During the building-up process the frequency of the received current increases from a very low value at point "a" until at point "b" it becomes the same as that of the source. The magnitude of the received current also increases until at point "b" it reaches a value corresponding to the steady-state transmission equivalent of the line. The interval "a-b" is determined solely by the structure of the line and has nothing to do with the time during which the current is supplied at the sending end.

The dying-out process can be considered to be caused by the application at the time of break of a second current equal in value to the current originally applied but opposite in phase, so that the sum of the two currents will be zero. Hence, it is to be expected that the received current will disappear by adding to the steady-state a transient similar to the building up transient in the interval "a-b." That this is true is indicated by the behavior during the interval "c-d." At first the low-frequency current of the break transient produces a displacement of the axis of the steady current. As the frequency approaches a steady value a beating effect becomes noticeable which grows smaller until complete opposition of phase obtains and the received current disappears.

Fig. 10 clearly indicates that a pulse of voice current having a frequency in the neighborhood of 1800 cycles, even though received in proper volume if steadily applied, would be badly distorted.

When carrying on a conversation over such a circuit as this, distortion of the voice waves makes understanding difficult while peculiar metallic ringing sounds are very noticeable.

Next consider a circuit of the same character with half the length. The effect of a circuit of this length on an 1800-cycle wave is shown in the oscillogram of Fig. 11. It will be observed that the propagation time has been cut in half while the lengths of time for the received wave to build up and die out have also each been cut in two. This checks with theoretical work, indicating that the severity of this type of transient effect is directly proportional to the length of the circuit. This fact that the transient effect is porportional to the length of the circuit furnishes the reason why a short circuit may give tolerably good results, while a long circuit gives poor results.

Fig. 12 is of interest as indicating what takes place when we apply a current at the sending end of the circuit whose frequency is so high that no appreciable amount of the steady current will pass through the circuit. In this case only transient oscillations appear at the receiving end of the circuit. This particular circuit was of the same type as the above, although it was only 350 miles long (570 kilometers).

A large number of oscillograms of this sort have been taken in connection with the study of these transient effects. From these and theoretical considerations[3] it has been proved that the effects in a given circuit are much worse at high frequencies than at low frequencies, the severity of the effects, within certain limits, being a function of the ratio of the frequency being transmitted to the frequency of cut-off of the loaded circuit. The gage of the circuit has practically no effect.

Since in order to give good quality it is necessary to transmit fairly well all frequencies up to at least 2000 cycles, it is obvious that on long circuits in order to keep the transient effects small, the frequency of cut-off must be kept high. In order to do this, it is necessary either to make the loading coils of very low inductance or to space them very close together. This is another one of the reasons why extra light loading was adopted for the long cable circuits. (It will be remembered that the inductance of the side circuit loading coils is only 0.044 henry and the spacing 6000 feet).

The effect of lighter loading on the transient behavior of telephone currents, is shown in Fig. 13, which shows a 2000-cycle wave transmitted over an x. l. l. circuit about 1050 miles (1700 kilometers) long. This circuit contained 23 one-way repeaters. It will be observed that both the building-up and dying-out transient periods are very much reduced, which means that all pulses of telephone currents up to at least 2000 cycles will pass through such a circuit with very little distortion.

Stability

As has been pointed out, the magnitude of the line transmission loss in a repeatered circuit is of comparatively small importance in determining its possible transmission equivalent, whether the circuit be worked on a four-wire or two-wire basis. However, it is of extreme importance to be sure that the repeater gains are kept adjusted so as to compensate exactly for a large part of the transmission loss in the circuit, so that the difference between the total loss in the circuit and the total gain, which represents the net equivalent of the circuit, will be kept constant.

On certain of the long circuits this difference is very small as compared to the quantities which are subtracted. For example, in the case of a 1000-mile four-wire circuit using x.l.l. 19 gage conductors, the total line transmission loss is about 500 miles. Not counting the gain required to make up for losses in apparatus and office cabling, the total gain is about 488 miles, the difference, 12 miles, representing the net equivalent.

3. John R. Carson—"Theory of the Transient Oscillations of Electrical Networks and Transmission Systems." Transactions of A. I. E. E. Vol. XXXVIII, page 407.

Evidently only a very small percentage change in either the transmission losses or the gains will have a large effect on the net equivalent. This represents about the most severe condition. Some examples of less severe conditions are:

2-Wire No. 19 m. h. l. circuit 200 miles long (320 kilometers). Line equivalent 58 miles. Repeater gain exclusive of gain required to make up for loss in apparatus and office cabling 46 miles. Net equivalent 12 miles.

4-Wire No. 19 m. h. l. circuit 500 miles long (800 kilometers). Line equivalent 145 miles. Repeater gain exclusive of gain required to make up for loss in apparatus and office cabling 133 miles. Net equivalent 12 miles.

In order to maintain the necessary constancy of the over-all or net transmission equivalent of long repeatered circuits in cable, it is necessary first of all to maintain the gains of the individual repeaters within close limits. In addition, periodic transmission measurements are required over the complete circuits, supplemented by suitable adjustment of certain of the individual repeaters whenever the over-all equivalent falls outside of the prescribed limits. Also, on the very long small gage circuits, the changes in attenuation, due to the resistance changes caused by temperature variations, become so large that it is practically essential to provide automatic means for overcoming these effects.

The methods employed in maintaining the gains of the individual repeaters and of the over-all transmission equivalents within proper limits will first be described, after which the automatic transmission regulators will be discussed.

Important Tests and Adjustments

In order to hold the repeater gains constant, close inspection limits are placed on the vacuum tubes during the course of manufacture to insure great uniformity of the product, as well as consistency of performance. In operating the repeaters, considerable care is taken to maintain constancy of the operating currents and voltages. The operating limits of currents and potentials together with the corresponding gain variations for one of the types of tube in common use are given in the following table:

Variable Quantity	Prescribed Limits	Gain Variation
Plate Potential	130 ± 5 volts	± 0.2 mile
Grid Potential	9 ± 1 volt	± 0.3 mile
Filament Current	1.25 ± 0.05 ampere	very small for new tube—one mile for tube just before replacement.

In addition to maintaining the tube currents and voltages within the required limits, the gains of the individual repeaters are checked periodically. Suitable adjustments are made when the repeater gains fall outside of the prescribed limits. When the filament emission of a tube becomes so low that the above specified variation in the filament current results in more than one mile gain variation, the tube is replaced.

A gain measuring device as indicated schematically in Fig. 14 is employed for this purpose. The measurement of gain is effected by comparison of the voltages across two resistances, one of which forms part of a circuit which includes the repeater, the other being simply a reference circuit. An amplifier-detector combination amplifies the voltages across these resistances and then rectifies them so as to obtain an indication on a d-c. galvanometer. Equality of voltages across the two resistances, which are designated as R and R' in the figure, is thus indicated by equal deflections of the galvanometer. When this condition is secured, the repeater gain is read directly from the dials A and B. By means of this device, it is readily possible to measure the gain of a repeater within a few tenths of a mile. Owing to the fact that the measuring circuits are comprised entirely of resistances, the readings of the set are independent of frequency, so that gains can be measured at all important telephone frequencies.

As pointed out above, transmission measurements over the complete circuits including the telephone repeaters are required at periodic intervals in order to insure that proper transmission standards are being maintained. By means of such measurements, the

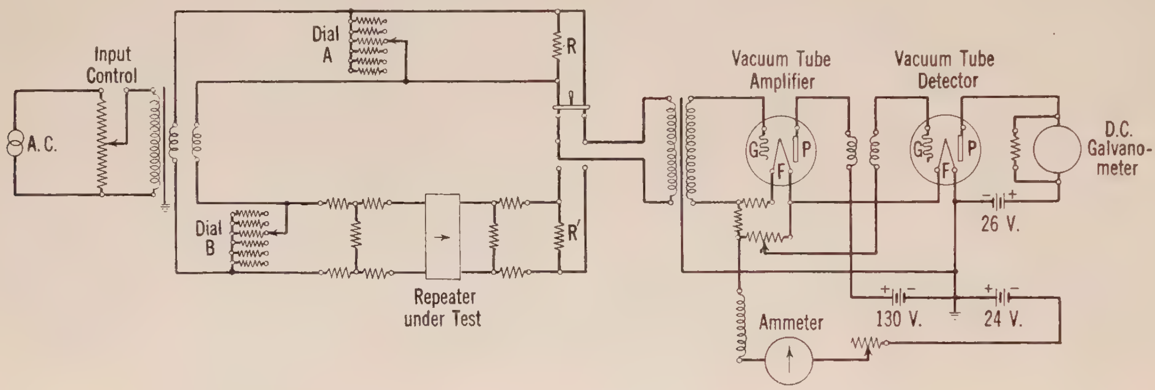


Fig. 14—Device for Measuring Telephone Repeater Gains

variations in the over-all equivalent of the circuits due to the cumulative effect of small gain variations, slight variations which remain after the automatic transmission regulators have compensated for the major variations in the conductors and variations from other causes including the effect of different conditions of humidity on the wiring in the offices, are determined and compensated for. These measurements are made by applying a known electromotive force through a known resistance to one end of the circuit and receiving the current at the distant end with a suitable calibrated arrangement employing an indicating meter. Since this type of measurement is similar in principle to the method employed for measuring the gains of the individual repeaters, it will not be described.

means automatic. In the case of x. l. l. No. 19 circuits whose variation is greatest, it is necessary to locate the automatic regulators, in general, at every third or fourth repeater station in order to keep the transmission levels within proper limits. In Fig. 1a, a typical method of locating the regulating devices along a cable is indicated. In this sketch each square indicates a master automatic transmission controlling device while the loops extending in either direction from the squares indicate the cable circuits which control the functioning of these devices.

An automatic transmission regulator is shown schematically in Fig. 15. The device comprises a Wheatstone bridge arrangement. In one arm of the bridge, pilot wire pairs, extending in either direction in

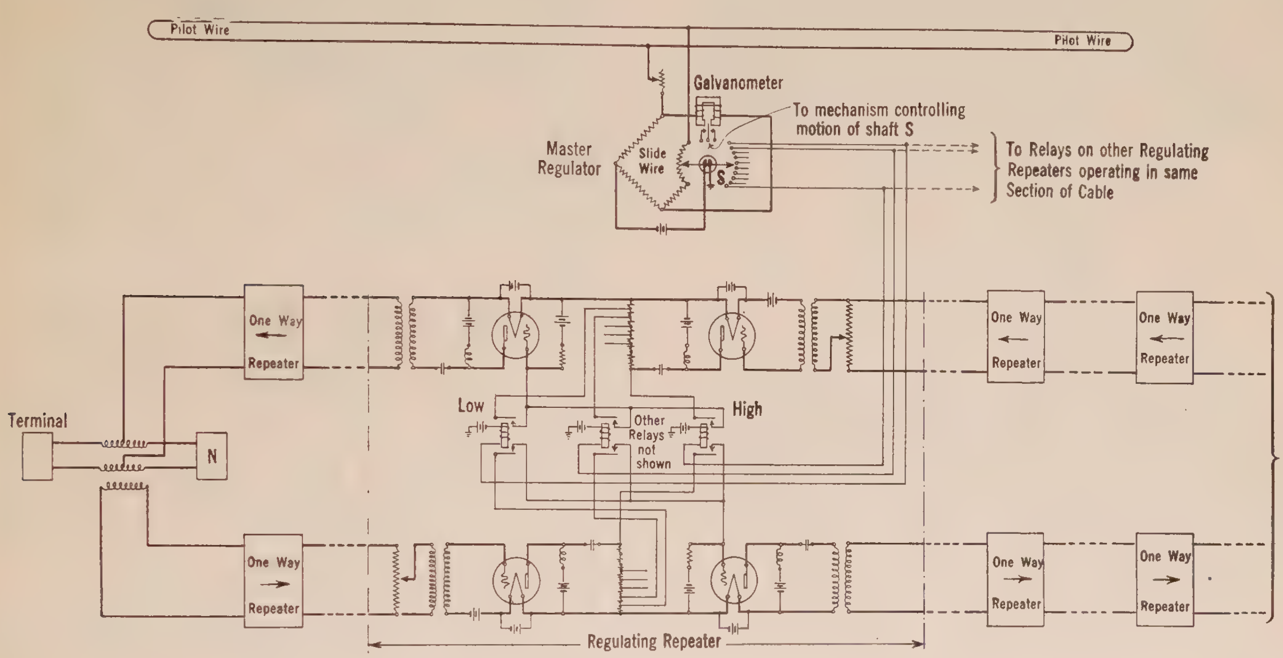


Fig. 15—Pilot Wire Automatic Transmission Regulator

Automatic Transmission Regulators

Since the resistance of long cable circuits employing small gage conductors is comparatively large, it is, of course, evident that changes in this resistance caused by temperature changes to which the cable circuits are subject will have a large effect on transmission. For example, in the case of an x. l. l. No. 19, 1000 mile circuit (1600 kilometers) in aerial cable, the total attenuation changes more than 110 transmission miles during the course of a year. This corresponds to a variation in the received power of more than 10^{10} or ten billion times.

It is, of course, essential to provide special means to counteract these effects. Furthermore, since the temperature changes which occur in an aerial cable are very rapid, it is practically essential to make these the cable, are included as indicated in the figure. The Wheatstone bridge has associated with it certain apparatus which will not be described here in detail, which functions in such a manner as to keep the bridge automatically balanced at all times. In the process of maintaining balance of the bridge, angular motion is conveyed to a shaft which is proportional to the resistance variations which the cable circuits undergo. The movement of the shaft causes different contacts to be made and thus controls relays which in turn control the gains of the telephone repeaters, one way of doing this being indicated in the figure. The repeater gains are thus caused to be raised and lowered automatically, and thereby overcome the differences in attenuation caused by the temperature changes in the cable conductors.

A New Equation for the Static Characteristic of the Normal Electric Arc

BY W. B. NOTTINGHAM

Associate, A. I. E. E.

Fellow of the American-Scandinavian Foundation

COMMERCIALLY the electric arc is now extensively used, and yet after more than a hundred years of study, there has been little crystallization of opinion as to certain phases of its fundamental theory. Absolute contradictions are frequently found in the literature, and premature generalizations have given rise to more disagreement among the investigators of the equation of the static characteristic of the normal[1] arc than the experimental difficulties warrant.

The static characteristic is the relation between the current (i) flowing in the arc, the length (L) of the arc, and the difference in potential (E) across the arc. This relation can be represented approximately by simple expressions of the form of the Ayrton[2] equation

$$E = a + b \cdot L + \frac{c + d \cdot L}{i} \tag{1}$$

or the Steinmetz[3] equation

$$E = a + \frac{c\,(L + d)}{i^{0.5}} \tag{2}$$

(a, b, c, and d are constants)

if the range in variation of the current and arc length, for which the constants are calculated, is the closely defined.

In particular, these equations are recognized as approximations, because *the difference in potential* (E) *is not a linear function of the arc length* (L), and although the difference in potential does decrease when the current increases, *the current* (i) *enters neither as the first power* (as in the Ayrton equation) *nor as the square root* (as in the Steinmetz equation). Duddell[4] was among the first to demonstrate by the use of the curve shown in Fig. 1, that, for arcs less than 15 mm. in length, the difference in potential cannot possibly be truly represented by a linear function of the arc length. As far as I know, Steinmetz[5] was the first to advance the thesis that, "while the stream voltage varies with the current, and in the opposite direction

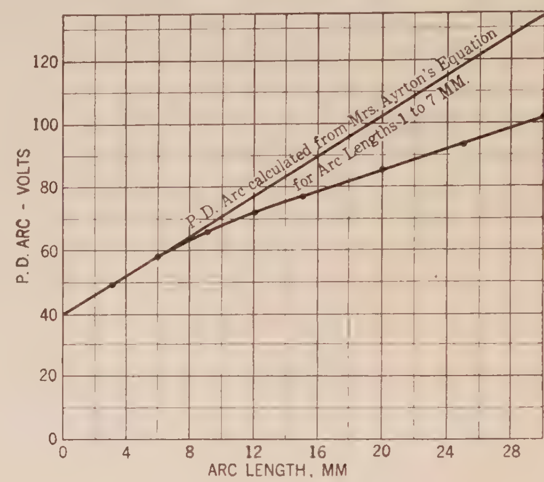


FIG. 1

to it, its variation is much less than the inverse proportion to the current."

This paper attempts to make these two criticisms constructive or positive instead of negative.

THE EXPONENT OF THE CURRENT IS DIRECTLY PROPORTIONAL TO THE TEMPERATURE OF THE BOILING POINT OF THE ANODE

If the arc length is assumed to be constant, the

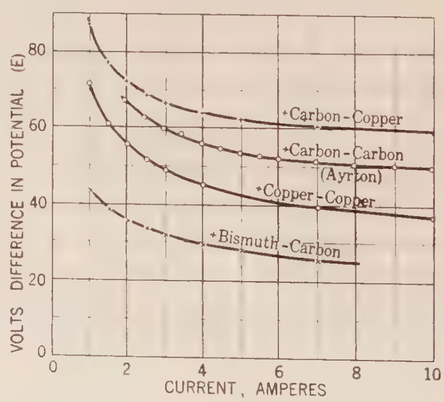


FIG. 2—VOLT-AMPERE CHARACTERISTICS WITH THE ARC LENGTH CONSTANT $L = 3.0$ MM.

Ayrton and the Steinmetz equations can be written in the form of equation (3)

$$E = A + B / i^{n} \tag{3}$$

1. Each stage of the electric arc from the glow arc to the hissing arc has its own physical, electrical and chemical characteristics. Therefore any equation of the electric arc must necessarily be limited to the characteristics of one stage. The normal arc has two general requirements: (1) the current intensity must be greater than the maximum for the glow arc, and less than the minimum for the hissing arc; and (2) the arc must be free from external electrical, magnetic, atmospheric, and physical disturbances.

2. Hertha Ayrton, The Electric Arc, "The *Electrician*," Printing and Publishing Company, London.

3. C. P. Steinmetz, TRANS. A. I. E. E., 1906, p. 802.
C. P. Steinmetz, "Radiation, Light, and Illumination," McGraw Hill, New York, 1909, p. 139.
C. P. Steinmetz, "Theory and Calculation of Electric Circuits," McGraw Hill, New York, 1917, p. 35.
C. P. Steinmetz, "Chem. and Met. Eng.," 22, p. 455, (1920).

4. W. Duddell, *Phil. Trans.*, 203 (A), p. 338, (1904).

5. See foot-note 3.

To be presented at the Midwinter Convention of the A. I. E. E., New York, N. Y. February 14-17, 1923.

in which A and B are constants dependent on the arc length and the electrode material and in which n is a constant dependent only on the electrode material. The value of n for the characteristic curves of an arc between any electrode materials can be calculated directly from curves such as those in Fig. 2. For example, the calculation of the constants of equation (3) for an arc 3.0 mm. long between copper electrodes, indicates that n is equal to 0.665. (See Fig. 2, Table I, and Equation (3a)). This study with copper electrodes was extended to include many characteristic curves for arcs ranging in length between 1.0 and 10.0 mm. The average value of n was found to be 0.670.

TABLE I

THE DETERMINATION OF n FOR AN ARC BETWEEN COPPER ELECTRODES

Anode—Copper Cathode—Copper

Arc Length 3.0 mm.

$A = 27.5$ $B = 44.0$

i Amperes	E Volts	$n = \frac{\log \frac{44.0}{E - 27.5}}{\log i}$
1.0	71.5	
1.5	61.0	0.677
2.0	55.5	0.652
2.5	51.5	0.668
3.0	49.0	0.653
4.0	45.0	0.660
5.0	42.5	0.670
7.0	39.5	0.669
10.0	37.0	0.667

Average $n_3 = 0.665$

Average for curves of 1.0 to 10.0 mm. arc length.................... $n_{ave.} = 0.670$

$$E = 27.5 + \frac{44.0}{i^{0.665}} \tag{3a}$$

It is generally agreed that n is equal to 1.0 for the characteristic curves representing the arc between carbon electrodes[6], while it has just been demonstrated that n is 0.670 in the case of the arc between electrodes of copper. The natural question arising from these observations is: what will be the value of n characteristic of an arc between *unlike* electrodes? The outcome of the first investigation was striking; it showed n to be 0.985 when the *anode* was *carbon* and the cathode was copper. This result indicates that the anode material predominates in the determination of n.

TABLE II

THE DETERMINATION OF n FOR AN ARC BETWEEN UNLIKE ELECTRODES

Anode—Carbon Cathode—Copper

Arc Length 3.0 mm.

$A = 56.0$ $B = 31.0$

Current Amperes	E Volts	$n = \frac{\log \frac{31.0}{E - 56.0}}{\log i}$
1.0	87.0	
1.5	77.0	0.960
2.0	72.0	0.955
2.5	68.5	0.992
3.0	66.5	0.985
4.0	64.0	0.997
5.0	62.5	0.970
7.0	60.5	0.993
10.0	59.5	0.950

Average $n_3 = 0.975$

Average for curves of 1.0 to 10.0 mm. arc length.............. $n_{ave.} = 0.985$

A continuation of this investigation of arcs between unlike electrodes not only supplied convincing evidence to substantiate the above thesis, but it opened the way to the discovery of the exact property of the anode material upon which n is dependent. It is apparent from Table III that there is a definite relationship between the value of n for each element represented and its boiling point. Furthermore, if the absolute temperature of the boiling point for each element is plotted as the abscissa and the corresponding value of n as the ordinate in a system of coordinates, the exact nature of the relation is at once evident (See Fig. 3.):

The exponent (n) *of the current* (i) *in the equation*

$$E = A + B/i^n \tag{3}$$

is directly proportional to the absolute temperature of the

TABLE III

THE RELATION BETWEEN n AND THE BOILING POINT OF THE ANODE

Anode	Cathode	Oxide[7] or Non Oxide on Anode	n	Abs. Temp. of Boiling pt. or Sub-limation pt.	Authority
Carbon	Copper	. .	0.985	3770	Van der Waals
Cadmium	Carbon	Oxide	0.720	2770	Approximation
Copper	Copper	Oxide	0.670	2580	Greenwood
Aluminum	Carbon	Al_2O_3	0.650	2480	Ruff—Schmidt
Nickel	Carbon	Oxide	0.640	2450	Hagenbach—Langbein
Silver	Carbon	Non oxide	0.624	2370	v. Wartenberg
Zinc	Carbon	Oxide	0.570	2170	Approximation
Lead	Carbon	Non oxide	0.480	1850	v. Wartenberg
Antimony	Carbon	Non oxide	0.460	1710	Greenwood
Bismuth	Carbon	Non oxide	0.445	1690	Greenwood

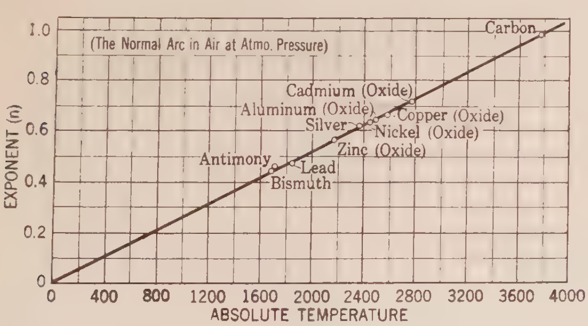


FIG. 3—THE EXPONENT (N) AND THE ABSOLUTE TEMPERATURE OF THE BOILING POINT OF THE ANODE MATERIAL

6. Calculations from Mrs. Ayrton's observed data indicate that n is slightly less than 1.0 for the arc between carbon electrodes.

7. G. Shulze, *Ann. d. Phys.* (4), 12, p. 828, (1903).
A. Hagenbach and K. Langbein, "*Archives des Sciences Physiques et Naturelles*," Vol. 5, Part 1, p. 48, (1919).

boiling point or the sublimation point, as the case may be, of the anode[8].

E is not a Linear Function of L when the Current is Constant

Both Mrs. Ayrton and Steinmetz have assumed the difference in potential (E) to be a linear function of the arc length (L) when the current is constant, but this is not even approximately true if the arc is less than 15.0 mm. in length. In spite of the fact that Duddell[9] made this criticism in 1904, as far as I know, no substitute has been offered for this much discredited assumption. A cursory examination of a typical constant current curve (which shows the relation between the difference in potential (E) across the arc and the length of the arc (L)) and its component parts will

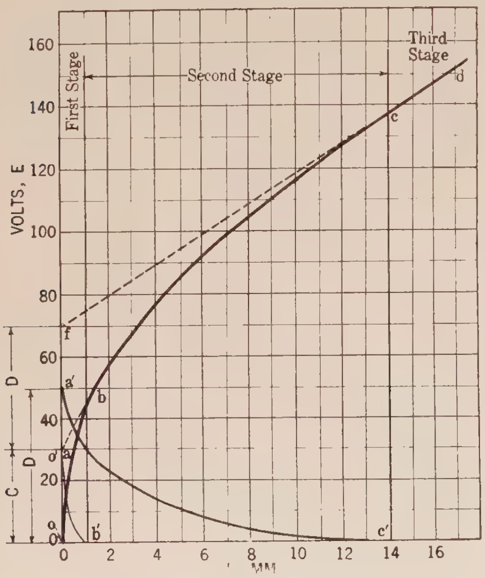


FIG. 4—A TYPICAL CONSTANT CURRENT CURVE AND ITS COMPONENT PARTS

reveal the steps to be taken in the formulating of a more accurate equation to supplant the old. (See Fig. 4.)

The arc goes through three distinct stages as it increases from an infinitesimal length to 15.0 mm. or more. These changes are in turn reflected in the constant current curves, and although the dividing line between the stages is not sharp, the first modification takes place when the arc length reaches 0.7 mm. to 1.0 mm. and the second when it is 13.0 mm. to 15.0 mm.

Arcs of the third stage can be represented easily, since the constant current curve is straight, by

$$E = D + C + \gamma \cdot L \qquad (4)$$

Furthermore, curve $a'\,c'$ (the difference between the straight line $f\,d$ and the constant current curve extrapolated) is so nearly a pure exponential of the form of the equation

$$e_2 = D \cdot \epsilon^{-d \cdot L} \qquad (5)$$

that the second and the third stages may be approximated very closely by the equation

$$E_{23} = C + D \cdot (1 - \epsilon^{-d \cdot L}) + \gamma \cdot L \qquad (6)$$

Curve $o'\,b'$, which is the deviation of $a\,b\,c\,d$ from the constant current curve, can be represented by the equation

$$e_1 = C \cdot \epsilon^{-d \cdot L} \qquad (7)$$

Therefore the equation of the constant current curve taken in its entirety[10] is

$$E = C \cdot (1 - \epsilon^{-d \cdot L}) + D \cdot (1 - \epsilon^{d \cdot L}) + \gamma \cdot L \qquad (8)$$

In the above equations

$C + D$ = the intercept of line $f\,d$ on the E axis,
C = the intercept of curve $o'\,b'$ on the E axis,
D = the intercept of curve $a'\,c'$ on the E axis,
γ = the slope of line $f\,d$,
$-\delta$ = the slope of the straight line represented by the equation $\log e_2 = \log D - \delta \cdot L$,
$-d$ = the slope of the straight line represented by the equation $\log e_1 = \log C - d \cdot L$.

Since equation (8) represents the curves in which the current is constant and equation (3) represents the curves in which the arc length is constant, a combination of these two equations will show the relation between the current (i) flowing in the arc, the length (L) of the arc, and the difference in potential (E) across the arc, without limitation. In other words, a new equation will have been derived to represent the static characteristic of the normal arc.

$$E = A + B/i^n \qquad (3)$$

THE NEW EQUATION

In order to discover just how equations (3) and (8) should be combined, the arc between copper electrodes was investigated. Constant current curves were plotted from the observed data. (See Fig. 5.)

The first curve analyzed was the one for a current of 1 0 ampere. This analyzation resulted in the determination of the numerical values of the constants in equation (8) so that it represented this curve showing

8. Although this law is being published at the present time, its confirmation is pending the investigation of a greater number of electrodes.

9. See footnote 4.

10. Equation (8) does not take into consideration the possibility that there may be, for each electrode material, an arcing potential below which no arc can be struck, however short it may be. This potential seems to be about 5.0 volts in the case of the arc between copper electrodes. If this observation is correct, equation (8) can be modified by the introduction of the constant ρ in the first term, so that the minimum potential for arcing is taken into consideration.

$$E = C \cdot (1 - \rho \,.\, \epsilon^{-d \cdot L}) + D \cdot (1 - \epsilon^{-\delta \cdot L}) + \gamma \cdot L$$

Where:

$$E_{min.} = C \,.\, (1 - \rho) \,.$$

Column Δ_a in Table IV shows the error between the observed and the calculated values of E when the modified form of equation (8) is used. The examination of the minimum potential for arcing would offer an interesting field for additional investigation.

the relation between the arc length and the difference in potential. The substitution of the values:

$$C = 28.0, \quad D = 42.5, \quad \gamma = 5.0, \quad d = 6.0, \quad \delta = 0.373,$$

in equation (**8**) gave (**9**).

$$E = 28.0\,(1 - \epsilon^{-6 \cdot L}) + 42.5\,(1 - \epsilon^{-0.373 \cdot L}) + 5.0 \cdot L \tag{9}$$

TABLE IV

THE COMPARISON BETWEEN THE OBSERVED AND THE CALCULATED VALUES OF E

Electrodes—Copper; Current—1.0 Ampere

E_c Calculated with equation (**9**)

Arc Length L mm.	Observed E_0 Volts	Calculated E_c Volts	Error Δ Volts	Error[11] Δ_a Volts
0.02	6.0	3.20	+2.40	−1.50
0.04	10.0	6.20	+3.80	−0.20
0.10	17.0	14.64	+3.36	−0.44
0.20	26.0	23.60	+2.40	+0.60
0.30	31.0	31.50	−0.50	−1.30
0.50	37.0	36.32	+0.68	+0.58
0.70	42.0	40.90	+1.10	+1.10
1.0	46.0	45.97	+0.03	+0.03
2.0	60.0	60.30	+0.30	+0.30
3.0	71.5	71.60	−0.10	−0.10
4.0	81.0	81.00	0.00	0.00
5.0	89.0	88.90	+0.10	+0.10
6.0	96.0	95.90	+0.10	+0.10
7.0	102.0	102.20	−0.20	−0.20
8.0	108.0	108.20	−0.20	−0.20
10.0	120.0	119.50	+0.50	+0.50

11. See footnote 10.

The difference in potential as observed and that as calculated by equation (**9**), have been placed in parallel columns in Table IV. The error (Δ) between the observed and the calculated values, is well within that attributable to experimental variations.

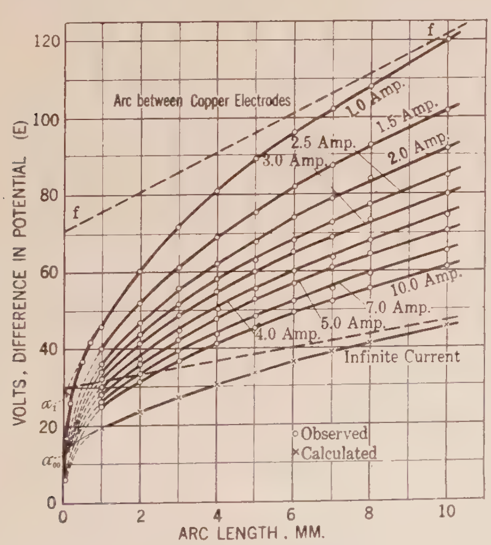


FIG. 5—VOLT-ARC LENGTH CHARACTERISTIC FOR DIFFERENT CURRENT VALUES

If the current is infinite equation (3) becomes

$$E = A = f\,(L) \tag{10}$$

Therefore, the curve showing the relation between the arc length and the constant A can be called the "infinite current" curve. (See Fig. 5.) Equation (**8**) represents this curve if the constants are assigned the following values:

$$C = 14.5, \quad D = 15.5, \quad \gamma = 1.7, \quad d = 6.0, \quad \delta = 0.235.$$

Hence, the second curve studied can be approximated very closely by equation (**11**). (See Table V.)

$$E = 14.5\,(1 - \epsilon^{-6 \cdot L}) + 15.5\,(1 - \epsilon^{-0.235 \cdot L}) + 1.7\,L \tag{11}$$

TABLE V

THE COMPARISON BETWEEN THE VALUES OF A AS DETERMINED FROM EQUATION (3) AND THAT CALCULATED BY EQUATION (11)

Electrodes—Copper Current—Infinite

A Determined by Equation (**3**)

A_c Calculated by Equation (**11**)

Arc Length L mm.	Determined A Volts	Calculated A_c Volts	Error Volts
1.0	19.6	19.43	+0.17
2.0	23.7	23.71	−0.01
3.0	27.5	27.48	+0.02
4.0	30.8	30.74	+0.06
5.0	33.8	33.74	+0.06
6.0	36.5	36.40	+0.10
7.0	39.0	38.90	+0.10
8.0	41.3	41.23	+0.07
10.0	45.5	45.52	−0.02

The numerical values of C, D, γ, δ, and d were also determined for each of the remaining curves in Fig. 5, and these values were plotted as functions of the current. In this way, it was discovered that d is independent of the current and that C, D, γ, and δ are functions of the current of the form of equation (**12**)

$$f\,(i) = a + \frac{b - a}{i^n} \tag{12}$$

In equation (**12**), a is the value of the constant when the current is infinite and b, the value when the current is 1.0 ampere. Therefore, in the case of the arc between copper electrodes, the constants of equation (**8**) may be expressed as functions of the current as follows:

$$C = 14.5 + \frac{28.0 - 14.5}{i^{0.67}} \tag{13}$$

$$D = 15.5 + \frac{42.5 - 15.5}{i^{0.67}} \tag{14}$$

$$\gamma = 1.7 + \frac{5.0 - 1.7}{i^{0.67}} \tag{15}$$

$$\delta = 0.235 + \frac{0.373 - 0.235}{i^{0.67}} \tag{16}$$

$$d = 6.0 \tag{17}$$

The substitution of the above functions in equation (**8**) gives (**18**), the desired final equation for the arc between copper electrodes.

$$E = \left(14.5 + \frac{28.0 - 14.5}{i^{0.67}}\right)(1 - \epsilon^{-6 \cdot L})$$

$$+ \left(15.5 + \frac{42.5 - 15.5}{i^{0.67}}\right)\left(1 - \epsilon^{-\left(0.235 + \frac{0.373 - 0.235}{i^{0.67}}\right) L}\right)$$

$$+ \left(1.7 + \frac{5.0 - 1.7}{i^{0.67}}\right) L \qquad \textbf{(18)}$$

As an indication that equation (**18**) is the characteristic equation sought, eighty-eight calculated values of the difference in potential have been placed beside the corresponding observed values in Tables IV and VI. Tables IV and VI indicate that equation (**18**) does fit these data without systematic error. However, if apparatus had been available for the study of arcs more than 10.0 mm. in length, the constants of equation (**18**) could no doubt have been determined with a higher degree of accuracy.

and for infinite current. For the curve for 1.0 ampere, let

$$C = \alpha_1, \quad D = \beta_1,$$
$$\gamma = \gamma_1, \quad \delta = \delta_1, \quad \text{and}$$
$$d = d$$

and for the curve for infinite current, let

$$C = \alpha_\infty, \quad D = \beta_\infty,$$
$$\gamma = \gamma_\infty, \quad \delta = \delta_\infty, \quad \text{and}$$
$$d = d$$

These constants incorporated in a general equation give equation (**19**).

$$E = \left(\alpha_\infty + \frac{\alpha_1 - \alpha_\infty}{i^n}\right)(1 - \epsilon^{-d \cdot L})$$

$$+ \left(\beta_\infty + \frac{\beta_1 - \beta_\infty}{i^n}\right)\left(1 - \epsilon^{-\left(\delta_\infty + \frac{\delta_1 - \delta_\infty}{i^n}\right) \cdot L}\right)$$

$$+ \left(\gamma_\infty + \frac{\gamma_1 - \gamma_\infty}{i^n}\right) \cdot L \qquad \textbf{(19)}$$

TABLE VI

A COMPARISON BETWEEN OBSERVED AND CALCULATED VALUES OF E

Electrodes—Copper

E_0 Observed Value of E

E_c Calculated by Equation (18)

Arc Length L	1 mm.		2 mm.		3 mm.		4 mm.		5 mm.		6 mm.		7 mm.		8 mm.		10 mm.	
Current 1 amp.	E_0	E_c	E_0	E_c	E_0	E_c	E_0	E_c	E_0	E_c	E_0	E_c	E_0	E_c	E_0	E_c	E_0	E_c
1.5	40.0	39.73	52.0	51 81	61.0	60.83	69.0	68.64	75.5	75.34	82.0	81.65	87.5	87.30	93.0	92.43	102.0	101.82
2.0	36.0	36.23	47.0	47.11	55.5	55.36	62.0	62.04	68.0	67.87	74.0	73.70	79.0	78.75	84.0	83.33	92.0	92.30
2.5	34.0	33.73	43.5	43.74	51.5	51.38	58.0	57.74	63.0	63.29	68.5	68.40	73.0	72.85	77.5	77.13	85.0	85.30
3.0	32.5	32.15	41.5	41.38	49.0	48.58	55.0	54.69	60.0	59.84	65.0	64.75	69.0	69.00	73.5	73.13	80.0	80.47
4.0	30.0	29.98	38.0	38.21	45.0	44.88	50.5	50.52	55.5	55.56	60.0	59.90	64.0	63.85	68.0	67.65	74.5	74.60
5.0	28.5	28.51	36.5	36.26	42.5	42.38	48.0	47.83	53.0	52.46	57.0	56.75	61.0	60.70	64.5	64.18	70.5	70.64
7.0	26.5	26.58	33.5	33.71	39.5	39.41	44.0	44.19	48.5	48.54	52.5	52.55	56.0	56.10	59.5	59.43	65.5	65.60
10.0	25.5	25.15	31.5	31.61	37.0	36.89	41.5	41.44	45.5	45.52	49.5	49.18	52.5	52.45	55.5	55.53	61.0	61.46

TABLE VII

THE CONSTANTS OF EQUATION (19) DETERMINED FOR TEN ARC CHARACTERISTICS

Anode	Cathode	n	α_∞	α_1	β_∞	β_1	γ_∞	γ_1	δ_∞	δ_1	d
Carbon	Copper	0.985	24.5	39.0	35.0	41.4	1.25	5.0	0.535	0.535	7.0
Cadmium	Carbon	0.720	10.0	15.0	9.2	37.5	0.80	5.0	0.220	0.229	7.0
Copper	Copper	0.670	14.5	28.0	15.5	42.5	1.70	5.0	0.235	0.373	6.0
Aluminum	Carbon	0.650	8.0	17.5	6.0	35.0	0.80	5.0	0 258	0.410	5.0
Nickel	Carbon	0.640	10.0	28.0	8.0	38.0	0.90	5.0	0.166	0.270	7.0
Silver	Carbon	0.624	13.0	27.5	7.0	37.5	0.80	6.0	0.229	0.246	7.0
Zinc	Carbon	0.570	8.6	24.0	2.9	41.0	0.65	5.0	0.210	0.263	7.0
Lead	Carbon	0.480	8.2	16.5	4.8	17.5	0.80	5.0	0.180	0.214	7.0
Antimony	Carbon	0.460	12.2	24.0	4.3	19.0	0.60	5.0	0.190	0.230	7.0
Bismuth	Carbon	0.445	7.8	17.5	6.2	24.5	0.80	5.0	0.187	0.200	7.0

Although equation (**18**) is an empirical equation derived as a result of the study of the arc between copper electrodes, it can be expressed in general terms and used to represent the static characteristic of any arc. It will be remembered that n was the first constant in equation (**18**) to be determined. This determination also yielded the values of A from which the curve for infinite current was plotted. (See equation (**3**) and Fig. 5.) The constants of equation (**8**) were then determined for the curves in Fig. 5 for 1.0 ampere

Equation (19) Tested for Ten Electrode Materials

All of the constants of equation (**19**) were calculated for the ten arc combinations studied and the resulting equations were checked graphically against the observed data. (See Table VII.)

The agreement between the observed and the calculated values was exceedingly close in every case. Therefore, *equation* (**19**) *is undoubtedly a truly general equation*

representing the static characteristics of normal arcs between any electrode materials.

THE CATHODE, ANODE, AND ARC FALLS AS COMFONENTS OP E

The three components of the difference in potential between the electrodes have long been recognized as the anode fall, the cathode fall, and the arc fall (See Fig. 6), but there is still some doubt as to the exact dependence of each on the current intensity and the arc length. The simplest of these, the arc fall, is

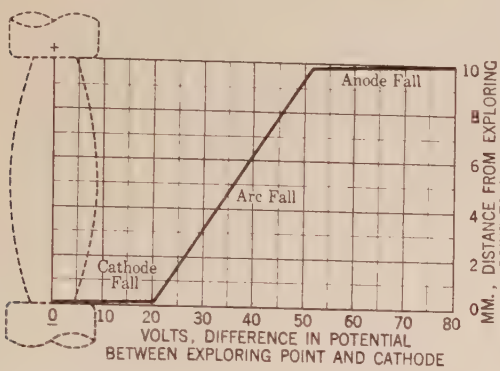


FIG. 6

generally thought to be a linear function of the arc length and a hyperbolic function of the current. If this is true, the arc fall (e_a) must be represented by the last term of equation (**19**).

$$e_a = \left(\gamma_\infty + \frac{\gamma_1 - \gamma_\infty}{i^n} \right) \cdot L \tag{20}$$

Some studies of the cathode fall have shown it to be independent of the arc length and the current. Although it is quite impossible actually to measure the cathode fall in arcs less than 1.0 mm. in length, the fact that arcs of 0.1 mm. can be maintained on less than 20.0 volts (Grotrian's[12] value for the cathode fall alone) invalidates the theory that the cathode fall is independent of the arc length when the arcs are short. A change in the magnitude of the cathode and the anode falls might naturally be expected when the arcs are short, because these falls take place in the space a fraction of a millimeter from the surfaces of the electrodes instead of exactly at their surfaces. In addition, it is apparent from the curves in Fig. 5 that the sum of the anode fall (e_b) and the cathode fall (e_c) can be neither independent of the arc length nor a linear function of the arc length. It is a plausible assumption that the cathode fall reacts upon the anode fall as the arc length becomes shorter until finally the two falls merge, and each rapidly cancels the effect of the other. This interaction may be measured roughly by the deviation of the slope of the curves for constant current from the minimum slope of these curves. The relation between the slope and the arc length for any particular current is expressed by equation (**21**).

$$\frac{dE}{dL} = \left(\alpha_\infty + \frac{\alpha_1 - \alpha_\infty}{i^n} \right) \cdot d \cdot \epsilon^{-d \cdot L} + \left(\beta_\infty + \frac{\beta_1 - \beta_\infty}{i^n} \right) \left(\delta_\infty + \frac{\delta_1 - \delta_\infty}{i^n} \right) \cdot \epsilon^{-\left(\delta_\infty + \frac{\delta_1 - \delta_\infty}{i^n}\right) \cdot L} + \left(\gamma_\infty + \frac{\gamma_1 - \gamma_\infty}{i^n} \right) \tag{21}$$

The curve in Fig. 7 is the graphical representation of equation (**21**) for an arc between copper electrodes when the current is 3.0 amperes.

Since the cathode fall is independent of the arc length for arcs longer than 1.0 mm., the second term of equation (**19**) must be a function of the anode fall. Therefore, this term represents either the *increase in* the anode fall as the arc length increases and the *change* in this increase as the current varies, or the *total anode fall* for any arc length and current. If the latter is the case, the first term of equation (**19**) represents the cathode fall for any current and arc length. Such conclusions would be in entire agreement with Mrs. Ayrton's[13] observations of the arc in its component parts.

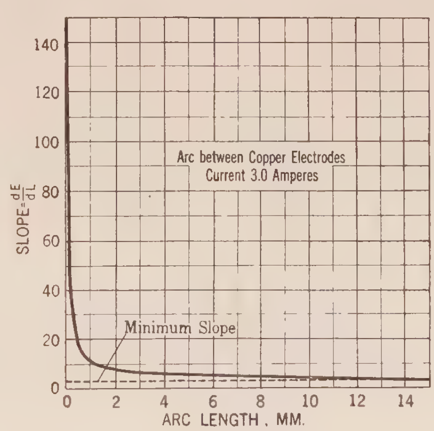


FIG. 7—A MEASURE OF THE INTERACTION OF THE CATHODE AND THE ANODE FALLS

It is evident from this examination of the equations (**19**) and (**21**) that arcs of less than 15.0 mm. can not possibly be represented accurately by an equation less complex than equation (**19**). However, arcs of a length greater than 15.0 mm. can be represented by equation (**22**) which is not unlike Mrs. Ayrton's in simplicity.

$$E = A + B \cdot L + \frac{C + D \cdot L}{i^n} \tag{22}$$

12. W. Grotrian, *Ann. d. Phy.*, 47, p. 141, (1915).

13. The Electric Arc, p. 238.

In equation (22),

$A = \alpha_\infty + \beta_\infty$, $\quad B = \gamma_\infty$,

$C = \alpha_1 - \alpha_\infty + \beta_1 - \beta_\infty$, and $\quad D = \gamma_1 - \gamma_\infty$

Although the results of this study are illuminating, they only point the way. A more extensive investigation of the arc in different atmospheres and at different pressures should be undertaken in hope that this equation, or some modification of it, will offer a method by which the arc characteristic can be studied in its component parts without the introduction of an exploring electrode. The equation might then be used to solve the many problems involving the distribution of the power consumption in the arc and the problem of determining the temperature in the arc, which now confronts the investigators of commercial arcs employed for the fixation of nitrogen, arc lighting, the electric furnace, etc.

Conclusions

1. The exponent n of the current i in the equation

$$E = A + B/i^n \qquad (3)$$

is directly proportional to the absolute temperature of the boiling point or the sublimation point, as the case may be, of the anode.

2. Equation (19) can be made to represent the static characteristic of the normal arc without apparent systematic error.

$$E = \left(\alpha_\infty + \frac{\alpha_1 - \alpha_\infty}{i^n}\right)(1 - \epsilon^{-d \cdot L})$$

$$+ \left(\beta_\infty + \frac{\beta_1 - \beta_\infty}{i^n}\right)\left(1 - \epsilon^{-\left(\delta_\infty + \frac{\delta_1 - \delta_\infty}{i^n}\right) \cdot L}\right)$$

$$+ \left(\gamma_\infty + \frac{\gamma_1 - \gamma_\infty}{i^n}\right) \cdot L \qquad (19)$$

3. Arcs more than 15.0 mm. in length can be represented accurately by the equation

$$E = A + B \cdot L + \frac{C + D \cdot L}{i^n} \qquad (21)$$

I wish to acknowledge my indebtedness to the American-Scandinavian Foundation whose fellowship made this work possible, and to Professor Gustav Grandqvist of Uppsala, Sweden and Mr. P. P. Cram for their assistance in the preparation of paper.

Appendix

The Description of the Apparatus. The electrodes were 12 mm. in diameter and made of the very highest grade of materials. After each reading the electrodes were refaced to insure precision in arc length measurements and to reduce the meter fluctuations to a minimum. The upper electrode was the anode except in the cases of the cadmium, antimony, bismuth and lead arcs.

Loosely fitting jackets supplied by independent water systems, were used to carry the excessive heat from the electrode supports. Readings taken with and without these jackets showed that this slight cooling had no appreciable effect on the arc characteristic.

For the longer arcs, the length was determined by the measurement of the image of the arc produced by a lens system (magnification 15 diameters) on a scale calibrated to read arc length directly in millimeters. The short arcs were adjusted by a micrometer screw.

The arc was freely open to the air at all times.

The Observed Data. The principal data from which the constants of the equations were calculated, are recorded in the following tables, *I* to *X* inclusive.

TABLE I

Anode—Carbon Cathode—Copper

Arc length *L*	1 mm.	2 mm.	3 mm.	4 mm.	5 mm.	6 mm.	7 mm.	8 mm.	10mm.
Current amperes	*E*	*E*	*E*	*E*	*E*	*E*	*E*	*E*	*E*
1.0	61.0	76.0	87.0	95.5	102.5	108.5	114.5	120.0	130.0
1.5	54.0	67.5	77.0	84.5	90.0	94.5	99.0	103.0	110.5
2.0	50.5	63.0	72.0	78.5	83.5	87.5	91.0	95.0	101.0
2.5	48.5	60.5	68.5	74.5	79.5	83.0	86.5	90.0	95.5
3.0	47.0	59.0	66.5	72.5	77.0	80.0	83.0	86.0	91.5
4.0	45.3	56.5	64.0	69.5	73.5	76.5	79.5	82.0	86.5
5.0	44.2	55.5	62.5	67.5	71.5	74.5	77.0	79.5	84.0
7.0	43.0	54.0	60.5	65.5	69.0	72.0	74.2	76.5	80.0
10.0	42.0	52.5	59.5	64.0	67.5	70.0	72.5	74.5	78.0

TABLE II

Anode—Cadmium (oxide) Cathode—Carbon

Arc length *L*	1 mm.	2 mm.	3 mm.	4 mm.	5 mm.	6 mm.	7 mm.	8 mm.	10mm.
Current amperes	*E*	*E*	*E*	*E*	*E*	*E*	*E*	*E*	*E*
1.0	27.5	38.5	48.5	57.5	65.5	73.0	80.0	86.5	98.0
1.5	24.0	32.5	40.5	47.5	53.5	60.0	65.0	70.5	80.0
2.0	21.5	29.0	36.5	42.5	48.0	53.0	57.0	62.0	67.5
2.5	20.5	27.0	33.5	39.0	43.5	48.0	52.0	56.0	63.0
3.0	19.5	25.5	31.0	36.5	40.5	45.0	48.5	52.0	58.0
4.0	18.0	23.5	28.5	32.0	36.5	40.5	44.0	47.0	52.5
5.0	17.5	22.5	27.0	31.0	34.0	37.5	41.0	44.0	49.0
7.0	16.3	20.5	24.5	28.0	31.5	34.0	37.0	39.0	43.5
10.0	15.5	19.5	23.0	26.5	29.0	31.5	34.0	36.0	39.5

TABLE III

Anode—Copper (oxide) Cathode—Copper

Arc length *L*	1 mm.	2 mm.	3 mm.	4 mm.	5 mm.	6 mm.	7 mm.	8 mm.	10mm.
Current amperes	*E*	*E*	*E*	*E*	*E*	*E*	*E*	*E*	*E*
1.0	46.0	60.0	71.5	81.0	89.0	96.0	102.0	108.0	120.0
1.5	40.0	52.0	61.0	69.0	75.5	82.0	87.5	93.0	102.0
2.0	36.0	47.0	55.5	62.0	68.0	74.0	79.0	84.0	92.0
2.5	34.0	43.5	51.5	58.0	63.0	68.5	73.0	77.5	85.0
3.0	32.5	41.5	49.0	55.0	60.0	65.0	69.0	73.5	80.0
4.0	30.0	38.0	45.0	50.5	55.5	60.0	64.0	68.0	74.5
5.0	28.5	36.5	42.5	48.0	53.0	57.0	61.0	64.5	70.5
7.0	26.5	33.5	39.5	44.0	48.5	52.5	56.0	59.5	65.5
10.0	25.5	31.5	37.0	41.5	45.5	49.5	52.5	55.5	61.0

TABLE IV

Anode—Aluminum (oxide) Cathode—Carbon

Arc length L	1 mm.	2 mm.	3 mm.	4 mm.	5 mm.	6 mm.	7 mm.	8 mm.	10mm.
Current amperes	E	E	E	E	E	E	E	E	E
1.0	34.0	47.0	56.0	65.5	73.0	79.5	85.5	91.0	102.0
1.5	28.0	38.5	45.5	53.0	58.5	64.0	69.0	74.0	82.0
2.0	25.0	34.0	40.0	46.0	51.0	55.5	60.0	64.0	71.5
2.5	22.5	30.5	36.0	41.5	46.0	50.0	53.5	57.0	64.0
3.0	21.0	28.5	33.0	38.0	42.5	46.0	49.5	52.5	59.0
4.0	19.0	27.5	29.5	34.0	38.0	41.0	44.0	47.0	52.0
5.0	18.0	23.5	27.5	31.0	34.5	38.0	40.5	43.0	47.5
7.0	16.0	21.0	24.6	28.0	31.0	33.0	36.0	38.0	42.0
10.0	15.0	19.0	22.5	25.0	28.0	30.0	32.0	34.0	38.0

TABLE V

Anode—Nickel (oxide) Cathode—Carbon

Arc length L	1 mm.	2 mm.	3 mm.	4 mm.	5 mm.	6 mm.	7 mm.	8 mm.	10mm.
Current amperes	E	E	E	E	E	E	E	E	E
1.0	42.0	53.5	64.0	73.0	81.0	88.5	95.0	101.5	113.5
1.5	35.5	44.0	53.5	60.0	67.0	73.5	78.0	83.0	93.0
2.0	32.0	39.5	47.0	53.0	59.0	64.0	69.0	73.0	82.0
2.5	29.0	36.0	42.5	48.0	53.0	58.0	62.0	66.0	74.0
3.0	27.0	34.0	39.5	45.0	49.5	54.0	57.0	61.0	69.0
4.0	24.5	30.0	35.5	40.0	44.5	48.5	51.5	55.0	61.0
5.0	23.0	28.0	33.0	37.0	41.0	45.0	48.5	51.0	57.0
7.0	21.0	25.5	29.0	33.5	37.0	40.0	42.5	45.5	50.5
10.0	19.0	23.0	27.0	30.0	33.0	36.0	38.5	41.0	46.0

TABLE VI

Anode—Silver Cathode—Carbon

Arc length L	1 mm.	2 mm.	3 mm.	4 mm.	5 mm.	6 mm.	7 mm.	8 mm.	10mm.
Current amperes	E	E	E	E	E	E	E	E	E
1.0	41.5	54.0	65.0	75.0	84.0	92.5	100.5	108.0	121.5
1.5	36.0	46.0	54.5	63.0	69.5	78.0	83.5	90.0	99.5
2.0	32.5	42.5	49.0	55.5	62.0	69.0	74.0	79.5	88.5
2.5	30.0	38.0	45.0	51.0	56.5	62.5	67.5	72.0	81.0
3.0	28.5	36.0	42.5	48.0	53.0	58.0	62.5	67.0	74.5
4.0	26.0	32.5	38.5	43.5	48.0	52.0	56.5	60.0	66.5
5.0	25.0	30.5	36.0	40.5	45.0	49.0	51.9	55.5	61.0
7.0	23.0	28.0	32.5	36.5	40.0	44.0	48.0	50.0	55.0
10.0	22.5	26.0	30.0	33.5	36.5	40.0	43.0	45.0	50.0

TABLE VII

Anode—Zinc (oxide) Cathode—Carbon

Arc length L	1 mm.	2 mm.	3 mm.	4 mm.	5 mm.	6 mm.	7 mm.	8 mm.	10mm.
Current amperes	E	E	E	E	E	E	E	E	E
1.0	38.5	51.0	61.0	71.0	79.0	86.5	93.5	100.0	112.0
1.5	33.0	43.5	51.5	59.5	66.5	72.5	78.0	83.0	92.0
2.0	30.0	39.0	45.5	53.0	59.5	64.0	69.0	74.0	81.0
2.5	27.5	36.0	42.0	48.0	53.5	58.0	63.0	67.5	74.0
3.0	24.5	33.5	39.0	44.5	49.5	54.0	58.0	62.0	69.0
4.0	23.5	30.0	35.0	40.0	44.0	48.0	52.5	55.0	61.0
5.0	22.5	28.0	32.5	37.0	41.0	44.0	47.0	50.0	55.0
7.0	20.0	25.0	29.0	33.0	36.0	39.0	41.5	44.0	48.0
10.0	18.0	22.5	26.0	29.0	32.0	34.5	36.5	39.0	42.0

TABLE VIII

Anode—Lead Cathode—Carbon

Arc length L	1 mm.	2 mm.	3 mm.	4 mm.	5 mm.	6 mm.	7 mm.	8 mm.	10mm.
Current amperes	E	E	E	E	E	E	E	E	E
1.0	25.0	32.5	40.0	46.5	53.0	59.0	65.0	71.0	82.0
1.5	22.5	29.0	35.0	41.0	46.0	51.0	56.0	61.5	71.0
2.0	21.0	26.5	32.0	37.5	42.5	47.0	51.0	56.0	64.5
2.5	19.5	25.0	30.0	35.0	39.5	44.0	48.0	52.0	60.0
3.0	18.8	23.5	28.5	33.0	38.5	41.5	45.0	49.0	56.0
4.0	17.5	22.5	26.5	30.5	34.5	38.0	41.5	45.5	52.0
5.0	17.0	21.0	25.0	29.0	32.5	36.0	39.5	42.5	49.0
7.0	15.8	19.5	23.5	26.5	30.0	33.0	36.0	39.0	44.5

TABLE IX

Anode—Antimony Cathode—Carbon

Arc length L	1 mm.	2 mm.	3 mm.	4 mm.	5 mm.	6 mm.	7 mm.	8 mm.	10mm.
Current amperes	E	E	E	E	E	E	E	E	E
1.0	33.0	41.0	48.5	55.5	62.0	68.0	74.0	80.0	91.0
1.5	29.5	36.5	43.0	48.5	54.0	59.0	64.0	70.0	79.0
2.0	27.5	33.5	39.5	45.0	49.5	54.0	58.5	63.0	71.5
2.5	26.0	31.5	37.0	42.0	46.0	50.0	54.5	58.5	66.5
3.0	25.0	30.0	35.0	40.0	44.0	48.0	51.5	55.5	63.0
4.0	23.5	28.0	33.0	37.0	40.5	44.5	48.0	51.5	57.5
5.0	22.5	27.0	31.0	35.0	38.5	42.0	45.0	48.5	54.5
7.0	21.0	25.0	29.0	32.0	35.5	38.5	41.5	45.0	50.0

TABLE X

Anode—Bismuth Cathode—Carbon

Arc length L	1 mm.	2 mm.	3 mm.	4 mm.	5 mm.	6 mm.	7 mm.	8 mm.	10mm.
Current amperes	E	E	E	E	E	E	E	E	E
1.0	27.0	35.5	43.5	51.0	58.0	64.5	71.0	77.0	88.5
1.5	24.0	31.5	38.5	45.0	50.5	56.5	62.0	67.0	78.0
2.0	22.5	29.0	35.5	41.5	47.0	51.5	57.0	61.5	71.0
2.5	21.0	27.5	33.5	38.5	44.0	48.5	52.5	57.0	66.0
3.0	19.5	26.0	32.0	37.0	41.5	46.0	50.0	54.0	62.5
4.0	19.0	24.5	29.5	34.0	38.5	42.5	46.5	50.0	57.0
5.0	18 0	23.0	28.0	32.0	36.0	40.0	43.5	47.0	54.0
7.0	16.5	21.5	25.5	29.5	33.0	37.0	40.0	43.0	49.0

DRY CELL SPECIFICATIONS

The Bureau of Standards has issued specifications for the standard sizes of dry cells and flashlight batteries. These specifications are a revision of similar specifications prepared several years ago, and published in the first edition of Circular No. 79, on the electrical characteristics and testing of dry cells. In revising these specifications the Bureau has received the hearty cooperation of the leading manufacturers and some of the largest individual users of dry cells. Special mention is made of the cooperation received from the American Telephone and Telegraph Company and the Signal Section of the American Railway Association.

Wind Shielding Between Conductors of Telegraph and Telephone Lines

BY P. J. HOWE
Associate, A. I. E. E.
The Western Union Telegraph Company

An investigation of the action of wind on telegraph and telephone lines is described in the following paper. The results of the tests made during this investigation show that the relation between wind velocity and wind pressure on ice covered conductors conforms closely to the generally accepted formula $P = KV^2$. They also indicate that the wires of such lines, when coated with ice, shield each other from the wind, both when carried on the same crossarm and on different arms.

OBSERVATIONS of the behavior of heavy telegraph lines during severe ice and wind storms have shown that such lines frequently withstand more severe ice and wind conditions than would be expected on the basis of theoretical considerations. Such observations have naturally given cause to question the soundness of the methods ordinarily followed in determining the ability of pole lines to resist heavy wind storms, and have indicated that the pressure of the wind on lines carrying many wires is not as great as the calculated pressure on one wire, multiplied by the number of wires on a line. In other words, it has for some time been felt that a shielding effect between wires exists when the wires are covered with ice, and are carried in such numbers and with such close spacing as is common practise on telegraph and telephone lines. In order to obtain information on this subject, a series of tests was conducted during the years 1916 to 1920 inclusive, for the purpose of answering, so far as practicable, the following questions:

(a) Is the formula $P = 0.0025\,V^2$, which is commonly used for calculating wind pressures on cylindrical surfaces, substantially correct when applied to the design of aerial pole and wire lines?

(b) Does shielding exist between telegraph and telephone wires carried on the same and on different crossarms, and to what extent?

The results of these tests were felt to be of such interest to all those concerned with the construction of telegraph and telephone lines, that this paper has been prepared with a view to making the information obtained generally available.

The tests were conducted on the Jersey meadows in the vicinity of Elizabethport, N. J. This location was chosen because the flat and open nature of the land permitted a free sweep of wind, unobstructed by anything which might cause unusual eddy currents. The nearest buildings, hills or depressions, in the direction from which fully 90 per cent of the winds blew were at least five miles away, while the distance in most directions was even greater.

Description of Testing Equipment

In order to carry out the proposed investigation it was necessary to devise a structure which simulated a section of telegraph line and, at the same time, was adapted for accurate measurement of the wind loads imposed upon it. Since the heaviest loading ordinarily considered for determining transverse strength of a pole line is that due to wind acting at right angles to the line on conductors coated with ice ½ in. in radial thickness, it was obvious that actual wires could not satisfactorily be used in carrying out the test. It was finally decided to employ wooden rods, 10 ft. long and 1-1/8 in. in diameter, to serve as the wires of the dummy line. Each rod thus represented a 10-ft. length of wire 1/8 in. in diameter, loaded with ice ½ in. in thickness.

The problem of designing a structure to carry these wires, and at the same time permit accurate measurement of the wind pressure on them, was one that required considerable experimentation before arriving at a satisfactory solution. One of the first features decided upon, however, and one that was retained throughout all tests, was that the wires, subject to a definite restraining force, should be free to move under the influence of the wind, and that the amount of deflection should be used as a measure of the force on the wires. By devising an instrument to record these deflections, and by applying known horizontal forces to the wires and noting the corresponding indication on the recording instrument, it was possible to determine exactly how much pressure on any wire unit was necessary to produce a certain deflection on the recording instrument.

A structure was built in the winter of 1916-1917 which carried all wires in a swinging frame, the motion of this frame being transmitted by mechanical means to recording meters. This arrangement was generally effective, but it proved lacking in refinements and accuracy, so that after constant experimentation during a period of two years, it was replaced by the structure and recording apparatus hereinafter described.

The structure used in the final tests, as shown in Fig. 1, was erected to represent to scale a 10 ft. section of a fifty-wire pole line, pivoted so it could always swing directly into the wind. The entire wire structure was mounted in the framework K, pivoted on ball bearings at F and G, and provided with a vane H.

The wires were spaced 12 in. apart and supported at each end by light steel channels (B, Fig. 2), 10 wires

being carried between each pair of channels to represent the load on one crossarm. (For convenience, each complete unit of ten wires and two channels will hereinafter be referred to as a "crossarm"). The crossarms

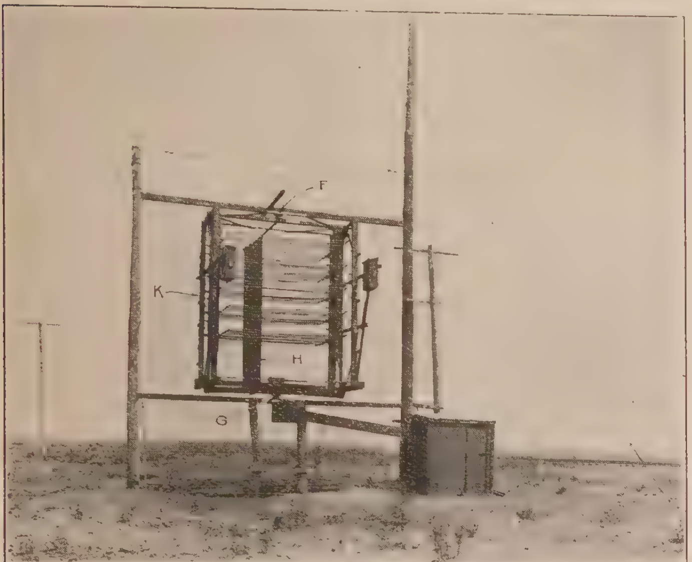


Fig. 1—Wind Test Structure

were spaced two feet apart vertically. Each crossarm was mounted independently of the other arms and carried on four hangers (*C*, Fig. 2) equipped with ball bearings at both ends, as shown at *D* in the same figure.

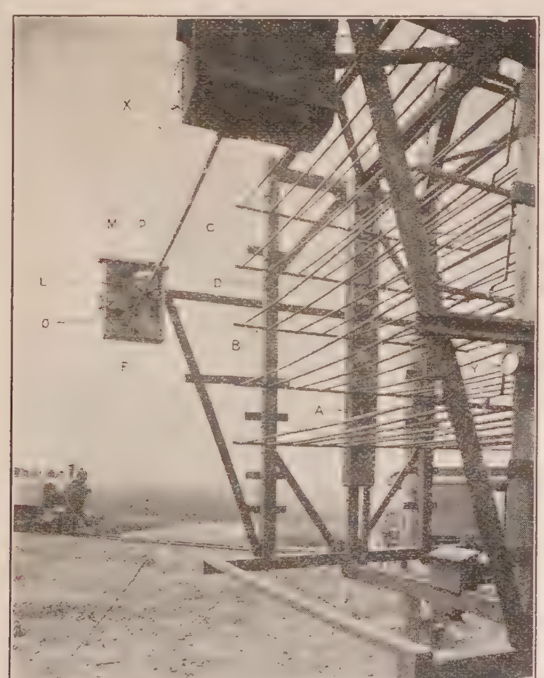


Fig. 2—Arrangement of Equipment on Wind Test Structure

The motion of the crossarms was restrained by springs, attached to two opposite hangers on each arm and to the framework, and adjusted so that all wires would move as nearly as possible in parallel planes.

In order to determine the relation between wind pressure on numbers of wires carried on crossarms and a single isolated wire, a 1-1/8 in. rod, representing one wire, was mounted about five feet in front of the structure and at an elevation approximately midway between the top and bottom crossarms. This single wire was supported in the same manner as the crossarms. The hangers may be seen at *L*, Fig. 2, the ball bearings at *M*, and the restraining springs at *O*, the arrangement of the latter also illustrating the method of attaching restraining springs to the crossarm hangers. The single wire hangers, springs, etc., were boxed in, in order to eliminate the effect of wind pressure on the hanger arms.

The instrument employed for recording the observations is shown in Fig. 3. It will be seen that this consisted of a specially designed recorder containing six independent recording mechanisms and pens, and

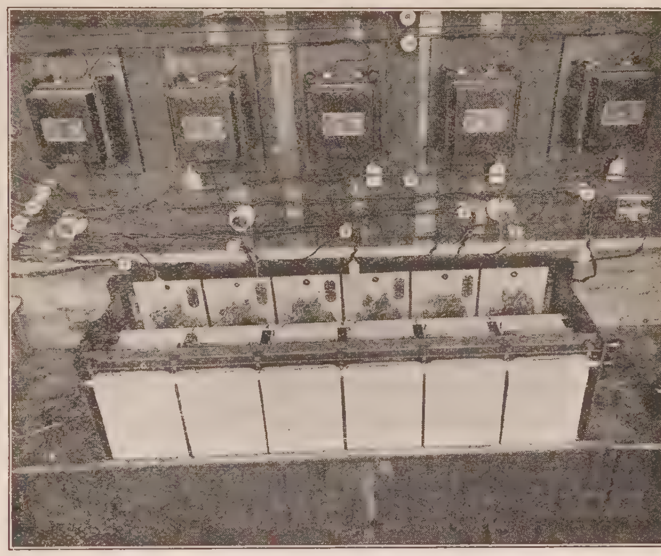


Fig. 3—Apparatus for Recording Crossarms and Wire Deflections

six charts driven simultaneously by a single, long roller. In order to transmit the deflections of the single wire and the various crossarms to the recording meter, the Bristol electric, long distance, motion recording system was employed. This system operates on the balanced induction principle and consists of two pairs of solenoids, arranged to swing horizontally back and forth over the end of soft iron cores, and connected in parallel to an alternating current circuit. One pair of solenoids is used for transmitting and the other for receiving, any motion of the transmitting coils being followed by a corresponding movement of the receiving coils and of the recording pen.

The complete measuring apparatus thus consisted of a transmitter mounted at each end of each crossarm and of the single wire, and of the corresponding recording mechanisms and charts, the recording instrument being arranged for making simultaneous records of the deflections of the single wire and of each of the

five crossarms. The transmitters were connected to the hanger arms by means of light metal rods. One single wire transmitter may be seen at *P*, Fig. 2, while those for the crossarms were mounted in two vertical boxes, one of which appears at *A*, in the same figure. The reason for using a transmitter at each end of the single wire and of each arm was to enable the recording instrument to record the average deflection of the wire or arm. By using the transmitters in pairs and cutting out one coil in each transmitter, it was possible to record the average movement of the two ends of the unit and thus compensate for any irregularities which might be caused by slight inaccuracies in adjustment.

The recording apparatus was mounted in a hut placed alongside the structure. The electrical connections between the transmitters and recorder were carried through the hollow pivot at the base of the framework by means of collector rings.

During early experiments, it was found that the records contained certain irregularities which were apparently caused by differences in the periods of the various recorder mechanisms. This difficulty was overcome by damping the motion of the recording pens, and of the arms and single wire, by the use of oil dash pots. By varying the amount of oil in the dash pots, it was possible to adjust all six recording systems so as to have approximately the same period.

In addition to the structure and apparatus described above for measuring wind pressure on a single wire and on ten-wire crossarms, it was also necessary to provide an instrument for indicating wind velocity in order to carry out that part of the investigation directed toward determining the relation between pressure and velocity, as expressed by the Formula $P = K V^2$. Various devices, such as an anemometer, a U-tube, and a Venturi tube, were experimented with for this purpose and the latter instrument finally decided upon as giving the most accurate results. The Venturi tube, connected to a direct reading wind gage, is a type of apparatus used by the United States Government in making tests of wind velocity in connection with aeroplane work. The complete unit, consisting of a Venturi tube and direct reading wind gage, used in this investigation was calibrated in the wind tunnel at the Bristol Company's factory to read actual wind velocities in miles per hour, and was subsequently standardized against a U-tube which was calibrated in the wind tunnels of the Navy Department at Washington, D. C. The Venturi tube was mounted on the test structure immediately alongside the single wire, and may be seen at *X*, in Fig. 2, the associated gage being shown at *Y* in the same figure.

Method of Making Tests and Working up Results

Preliminary to making any tests, it was of course necessary to calibrate carefully all instruments and equipment. The direct reading wind gage was calibrated as described above. The instruments for recording the deflections of the single wire and crossarms were calibrated by applying known horizontal forces to each of the units. A piece of flexible cord was fastened at each end of the wire or arm to be calibrated, and run over a pulley a few feet distant. Known weights were then suspended from the free end of each cord and the deflections on the corresponding charts of the recording instrument noted. A large number of readings were taken in this manner for each arm and

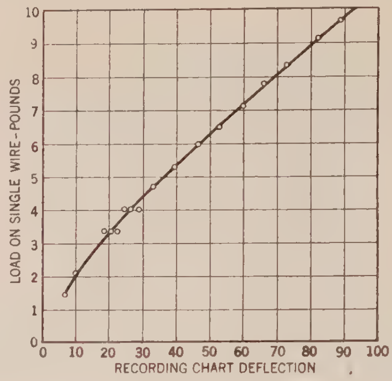


Fig. 4—Calibration Curve—Single Wire

for the single wire, care being taken to perform the work when there was no wind blowing. Similar calibrations were also made under impact loads, in order to make sure that inertia characteristics were equalized as nearly as possible.

In the early experiments, it was found that the best records could not be obtained at low wind velocities without sacrificing considerable accuracy and efficiency in the upper ranges. The recording instruments and wire units, therefore, were so adjusted that the greatest

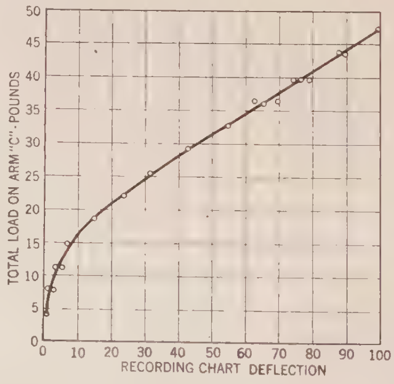


Fig. 5—Calibration Curve—Arm "C"

accuracy would be obtained with loads corresponding to actual velocities of approximately 30 miles per hour or over. Sample calibration curves are shown below, Fig. 4 showing the calibration for the single wire, and Fig. 5 for crossarm *C*, the middle arm on the experimental line. (For convenience, the several crossarms are designated by letters *A*, *B*, *C*, *D*, and *E*, reading from the top downward).

Having placed all equipment and apparatus in

working condition and having completed all calibrations, it was only necessary to wait for favorable weather conditions, in order to obtain the desired records. The majority of test observations and readings were made during the months of February and March, since it was found that the steadiest and highest winds occurred at that time. All equipment was frequently calibrated during this period so as to prevent any possibility of changed conditions affecting the accuracy of the final results.

In order to determine the relation between wind velocity and wind pressure on a single wire, simultaneous

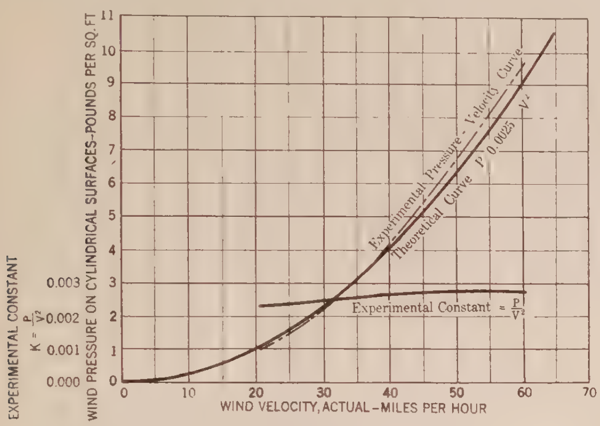


Fig. 6—Pressure Velocity Curve

observations were made, during periods of heavy wind, of the readings on the wind velocity gage and those on the chart recording the deflections of the single wire. Numerous tests were conducted in this manner and the velocities as obtained from a great number of readings, plotted against the corresponding pressures on the wire. The results thus obtained are shown by the dot and dash curve in Fig. 6, which also shows for comparison the theoretical curve plotted from the formula $P = 0.0025\,V^2$, in which P is the pressure in pounds per square foot of projected area and V is the actual wind velocity in miles per hour.

In order to carry out the shielding tests, and obtain data necessary for this part of the investigation, it was only necessary to determine how the total pressure on all the wires of the structure compared with that on the single wire, during periods of high wind velocity. At the beginning of each test, all charts were carefully marked with starting points and with the name or letter of the units whose motion they were to register. The roller carrying all six charts was then set in motion and the deflections corresponding to simultaneous pressures on all units recorded.

After the completion of each test, the charts were laid out so that the deflections recorded at the same instant by the single wire and the various crossarms could be noted. Points were then chosen at suitable intervals on the single wire deflection curve and the deflections which crossarms recorded at the same instant tabulated opposite these single wire deflections. The following table shows a sample of some of the actual test results obtained in this manner, each value of crossarm deflections being the average of numerous readings.

SAMPLE OF TEST RESULTS
(50 WIRES ON LINE)

Deflection Single Wire	Average Deflection Arm C.
7.5	6.5
12.5	9.0
17.5	12.1
22.5	15.1
27.5	19.0
32.5	23.3
37.5	26.9
42.5	31.7
47.5	35.0
52.5	39.7
57.5	44.0
62.5	49.6
67.5	53.0
87.5	72.0
92.5	78.3

Tests were made in the above manner with all five crossarms in place on the structure. Tests were also made with 40, 30, 20, and 10 wires on the line, one arm of wires being removed just previous to each series of tests, the removal of arms being in the order *A*, *E*, *B*, and finally *D*.

In order to put the data obtained from the above tests in convenient form for study, curves were plotted from the tabulated deflections, the deflections of the crossarms being plotted as ordinates and those of the single wire as abscissas.

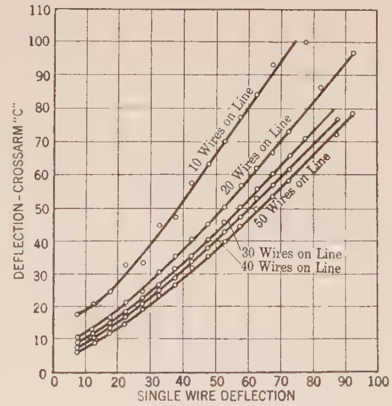


Fig. 7—Arm *C*—Observed Deflections

The lower curve in Fig. 7 is plotted from the data given in the foregoing table and shows the deflections of Arm *C* when there was a total of 50 wires on the line. Similar curves were also plotted for each of the other arms, and in addition, a set of curves for each wire load, 40, 30, 20, and 10 respectively. The complete set of curves for arm *C* in shown in Fig. 7.

By applying the proper calibration curves to the deflection curves above described, it was possible to transform deflections to loads and to obtain new sets of curves showing the direct relation between forces on the several crossarms and that on the single wire. The

lower curves in Fig. 8 were obtained in this manner, and show the force of the wind on each crossarm during the test of 50 wires. The upper curve in this figure shows the total load on all 50 wires, and was obtained by adding together the corresponding ordinates for the five ten-wire crossarms. Curves similar to Fig. 8 were made up to show total loads on 40, 30, 20, and 10 wires.

In discussing wind test results, however, it is desirable to refer to pressure in terms of pounds per square foot,

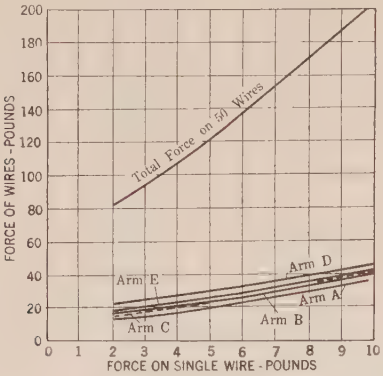


Fig. 8—Wind Load on Crossarms (50 Wires on Line)

rather than to total pressures on any number of given wires and, therefore, these latter curves were again transformed to a new set based on unit pressures. Fig. 9 was obtained by dividing the total loads plotted in Fig. 8 and the other similar curves by the projected area in square feet of the wire or wires on which the pressures were observed. These curves show admirably the relation between the unit pressure on a single wire and that on a number of wires subjected to the same wind velocity. The curves in Fig. 10,

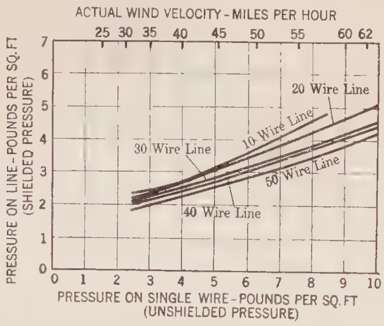


Fig. 9—Shielded and Unshielded Pressures

which show the actual per cent of shielding at different wind velocities, were next made up by dividing the unit pressure on the line (shielded pressure in Fig. 9) by the unit pressure on the single wire (unshielded pressure in Fig. 9). In order to make the curves more convenient for general use, they were plotted against velocities instead of pressures, the velocity ordinates being determined from the test pressures by the use of the formula $P = 0.0025\ V^2$.

Discussion of Results

It will be seen that the experimental curve in Fig. 6, plotted from the results of the tests made to determine the relation between wind velocity and wind pressure on a single wire, differs very little from the theoretical curve plotted from the Formula $P = 0.0025\ V^2$. In fact, the experimental curve gives for the constant $K = P / V^2$, a value which averages close to the commonly used value of $K = 0.0025$, no point differing more than 8 per cent from this figure. The results of this test, therefore seem to substantiate the use of the commonly accepted formula for the determination of wind loads on wire lines. Furthermore, this test, assuming the accepted constant to be correct, gives an indication as to the probable accuracy of the results of the wind tests as a whole.

In considering the matter of shielding, it must be borne in mind that the shielding tests were made upon a structure designed to represent to scale a telegraph line having ice covered conductors spaced 12 in. apart on ten-pin crossarms, which themselves were spaced

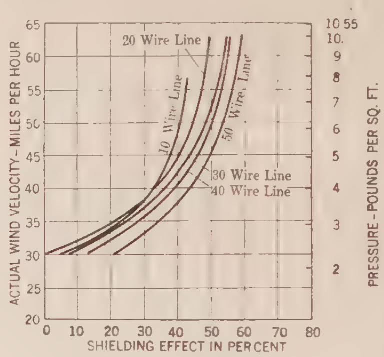


Fig. 10—Variation in Shielding with Wind Velocity

two feet apart, center to center. The results described below, therefore, may only be considered strictly applicable to telegraph or telephone lines loaded as indicated, and having conductor and crossarm characteristics similar to those represented by the test structure. It is, of course, reasonable to suppose that shielding would probably be greater with a closer spacing of conductors or crossarms, or an increased thickness of ice on the wires, and also that it would be smaller with a greater separation or less ice, but the tests were not carried far enough to warrant any definite statements in this respect.

In analyzing the results of the tests, consideration should first be given to the behavior of arm C, the middle arm, with various numbers of additional wires on the line. By referring to Fig. 7, it will be noted that the deflection of arm C, corresponding to any given deflection of the single wire, decreases as the number of crossarms or wires on the line is increased. Thus the deflection of arm C corresponding to a deflection of 60 for the single wire, is 80, with 10 wires on the line, but only 46.5, when the number of wires is increased to 50.

These values of actual comparative deflections, considered entirely without reference to calibrations for wind pressures or velocities, prove unquestionably that the deflection, and consequently the pressure, on one arm decreases as the number of wires on the line increases. In other words, they establish definitely the fact that shielding exists between crossarms.

Next considering the curves shown in Fig. 9, it is possible to gain an idea of the shielding between wires carried on the same crossarm, and also of the amount of shielding under different wind conditions. For example, when the pressure on the single wire amounted to 8 pounds per square foot, the pressure recorded on a line of ten wires was only 4.6 pounds per square foot, demonstrating that there is a very marked shielding effect between wires carried on the same crossarm, as well as between wires carried on different crossarms. Furthermore, corresponding to the pressure of 4.6 pounds per square foot on a ten-wire line, the tests showed a unit pressure of only 3.4 pounds per square foot when there were 50 wires on the line. A similar relation will be found to exist when any other unit pressure on the single wire is taken as a basis of comparison.

From the curves of Fig. 10, can be read directly the per cent of shielding which was shown by the tests to exist with various numbers of wires on the line and at different wind velocities. Thus, at a wind velocity of between 25 and 30 miles per hour, the shielding is apparently near zero, judging from the slope of the curves. In fact, the twenty-wire curve shows a zero value of shielding at a velocity of about 30 miles per hour, although the fifty-wire curve at the same velocity indicates approximately 20 per cent of shielding. The small shielding found at these comparatively high velocities is probably due to the fact that, as previously stated, it was found impracticable to adjust the recording instruments to give accurate results at low wind velocities without sacrificing accuracy in the upper ranges. It will be noted that the shielding increases with the wind velocity, varying from about zero at velocities of from 25 to 30 miles per hour to as high as 59 per cent at velocities of about 62 miles per hour, with fifty wires on the line. Furthermore, it appears that the shielding increases most rapidly between 30 and 40 miles per hour, above which the rate of increase gradually becomes less. Few observations were made at wind velocities higher than 60 miles per hour, but the curves indicate that the shielding does not increase greatly above this velocity. At an actual velocity of 57 miles per hour, which corresponds to the pressure of 8 pounds per square foot that is ordinarily assumed as the condition of heavy loading, the shielding effect varies from a minimum of about 43 per cent on a ten-wire line to approximately 57 per cent on a fifty-wire line.

In designing telegraph and telephone lines for situations of hazard, it has often been the practise in calculating transverse loads to assume a wind pressure of 8 pounds per square foot of projected area on wires covered with ice ½ in. in radial thickness, and then to neglect one-third of the number of wires carried—that is, to assume a shielding effect of 33-1/3 per cent. In the present investigation, tests show, as indicated in Fig. 10, that under a wind velocity of 57 miles per hour, which corresponds to a pressure of 8 pounds per square foot, the shielding effect varies from a minimum of about 43 per cent on a ten-wire line to approximately 57 per cent on a fifty-wire line. Evidently, therefore, the assumed shielding effect of 33-1/3 per cent is very conservative, since it is but 60 to 75 per cent of that shown by the tests for this velocity. It is hardly probable that the investigation contained any errors large enough to make up this difference, especially in the tests made at wind velocities exceeding 40 miles per hour.

Accuracy of Results

While during the entire investigation of wind pressures every precaution was taken to insure the results being as accurate as possible, there still remain a number of factors whose influence should not be overlooked.

In the first place, the structure used to support the crossarms was necessarily within such distance of the wires that it may have influenced the wind currents to some extent. Furthermore, there was probably a slight "end effect" at the ends of the wooden rods where they were supported by the thin steel channel crossarms. At the most, however, this latter effect could not have altered the results by more than one per cent since the length of the span was roughly 100 times greater than the diameter of the rods.

Secondly, it was not found possible to obtain exactly similar characteristics in the several recorders nor to make the inertia of the single wire exactly proportional to the inertia of the several ten-wire units. For this reason, it was not practicable to obtain simultaneous observations of wind gusts which would be truly comparative. Although this condition was largely compensated for by oil damping, as previously described, applied to the movable wires and the recording apparatus, the actual effects were still further eliminated by working up the results only from points on the charts which were practically free from sudden changes in wind velocity. It is believed that this procedure, together with the fact that large numbers of points were averaged, practically eliminated all errors due to inertia.

Another condition which possibly influenced the results was that the steel suspension members from which the crossarms hung were not shielded from the wind. On the basis of the relatively small area these hangers presented to the wind, the error from this cause could not have exceeded one per cent and, therefore, was neglected. The hangers supporting the single wire were shielded from the wind and hence were not a source of error.

Another difference between the experimental line and a real line is that in the latter, the swaying of wires and poles causes constant variation in the position of the wires with respect to each other, while in the experimental line, the sags of the wooden rods were more constant, although not entirely uniform. While this characteristic of a real line could not, of course, be duplicated, the wires of the experimental line, nevertheless, assumed positions quite similar to those of a real line, since the natural warping of the wooden rods caused many irregularities in the sags of the different wires.

The above paragraphs discuss the principal sources of error which are known to exist. There is still another respect in which the conditions in a real open wire line could not be simulated in the experimental structure. The inertia of wires heavily loaded with ice tends to absorb much of the energy of sudden gusts of winds, before the force of the wind is finally transmitted to the supporting poles. On the other hand, the swaying of heavy wires under the influence of sudden and variable gusts of wind probably at times causes momentary forces on the supporting poles which may even exceed the direct pressure of the wind at any one instant. These conditions are obviously too complex to be duplicated in a short span line such as used in the present investigation, but their absence from the experimental line could hardly have affected the relation between the wind pressures on the single wire and the multiple wire units, which relation was the primary thing that the investigation was to determine.

It will be seen from the foregoing discussion that such inaccuracies as may have entered into the results of the tests were comparatively small. In fact, the relation between wind pressure and wind velocity was found to be approximately the same as that which other investigators have determined, the maximum difference between the experimental constant K, and the commonly accepted value, being within 8 per cent and the average difference only 3.6 per cent. It therefore seems safe to assume, for practical purposes, that the wind pressures recorded in these tests and the results deduced from them were accurate within 10 per cent.

Conclusions

The final results of the wind pressure investigation described in this paper may be summarized as follows:

1. The formula $P = 0.0025\, V^2$, in which P is the pressure in pounds per square foot of projected area on cylindrical surfaces, and V is the wind velocity in miles per hour, may be used in calculating wind pressures on *unshielded* ice covered conductors.

2. A definite shielding effect exists between ice covered telegraph and telephone conductors carried on the same crossarm and closely spaced (about 12 in. center to center) as in modern telegraph and telephone practise.

3. A similar shielding effect also exists between such wires carried on different crossarms spaced two feet apart.

4. The amount of shielding on any number of wires increases with the wind velocity, and vice versa.

5. The shielding at any wind velocity varies with the number of wires, increasing as the number of wires increases, and vice versa.

6. On telegraph and telephone lines having conductors coated with ice ½ in. in radial thickness, the total shielding effect at wind velocities corresponding to a pressure of 8 pounds per square foot, even allowing a 10 per cent reduction from the test results in order to compensate for possible inaccuracies, will run from a minimum of 39 per cent on a ten-wire line to as high as 51 per cent on a fifty-wire line.

The author desires particularly to acknowledge his obligation to Mr. R. Leedom, who personally carried out most of the work of the investigation above described, and his appreciation of the valuable assistance rendered by Mr. C. P. Siedler in the preparation of this paper.

CORRECTING VALUES OF FUNDAMENTAL ELECTRIC UNITS

The electrical units which are in use in the measurment of power and in various scientific and technical investigations are what are known as the international electrical units. These units were intended to be the same as the corresponding units based on the centimeter, gram, second system of units. However, the fundamental measurements on which the specifications for these units are based were made more than 30 years ago.

In the meantime there has been a marked improvement in electrical measurements generally, and a few fundamental measurements made more recently show that the magnitudes of some of the international electrical units differ from the magnitudes they were intended to have by fully one part in two thousand. Consequently, if we are to have and use electrical units which are to be considered definitely a part of the general system of units so that, for example, a watt measured electrically and a watt measured mechanically shall be the same, we must make suitable measurements in such a way as to determine the magnitudes of electrical quantities in terms of the units of the fundamental magnitudes, namely, length, mass, and time.

The Bureau of Standards is, therefore, taking up again work on fundamental electrical units which was begun soon after the Bureau was established, but which had to be discontinued some years ago. The work now in progress is on the measurement of inductance and resistance. Presumably work on the measurement of current will be taken up after work on these two has reached a satisfactory stage.

To make the results of this investigation more reliable and to reach a fair estimate as to their reliability, it is planned to carry out the measurements in different laboratories using independent observers, and as far as possible independent methods of measurement.

The Automatic Train Control Problem

BY E. J. BLAKE
Associate, A. I. E. E.
Electrical Engineer, Gould Coupler Co.

Circumstances which make train control a pressing problem at the present time are mentioned. Certain desiderata are briefly discussed; the automatic control should act as a check on the proper exercise of manual control, not as a substitute; should conform to established safe signaling practises; should be designed for the severe conditions of railway operation; should not conflict with existing signals or otherwise introduce new hazards; should so far as possible conform to existing clearance lines; should not impede traffic; may be desired to exercise signal as well as control functions; may ultimately be desired for interlocking plants as well as main line tracks. Methods of transmitting and indication of track conditions to the train are described, (1) by intermittent mechanical and electric contact; (2) by intermittent induction through the use of permanent or electromagnets; (3) by continuous induction from the rails. Two general types of controlling action on the train are described, with some of their variations; (1) unconditional stop effective at a stop signal, with overlapping signal control, and (2) conditional stop effective at a caution signal. Relations between the type of controlling action and traffic capacity are discussed.

THE problem of mechanically enforcing observation and obedience of railway signals has attracted inventors and engineers for many years; but until very recent years railway officials have been inclined to view automatic train control as something rather Utopian; highly desirable no doubt, but too remote to command serious attention when the resources of the railroads were already taxed to provide other and more pressing improvements in the interest of safety; for example, extensions of existing signal systems and elimination of grade crossings. Within the last few years, however, a large number of disastrous wrecks attributed to disregard of signal indications have brought home the need for some effective check on the functioning of human, and therefore fallible engineers. The Interstate Commerce Commission has commented on the need with increasing emphasis, and finally has ordered automatic control installed on a large mileage of important lines. The train control problem thereby becomes so urgent that it is believed a brief review of the characteristics desired in automatic train control devices and of the broad features of some systems now available may have some general interest.

The roadside signal systems already installed on the principal railroads are adequate in so far as regards the detection and indication by visible signals of the presence of trains or other danger conditions along the track beyond the signal. The present demand is for an automatic device to bridge the gap between signals properly displayed, and trains properly controlled in accordance with the signal indications. The kernel of all modern roadside signal systems is the continuous track circuit consisting of the track rails, extending through the length of the block, a source of low-volt d-c. or a-c. power at one end and a relay at the other end. So long as the track is unoccupied and the rail circuit intact, the relay is held closed by current passing through the rails from end to end of the block, and establishes local circuits to cause the clear, or safe signal indications to be displayed. But if the rail circuit is interrupted, or short-circuited by a train in the block, the relay is deprived of power and opens, and the signal reverts to its restrictive indication. Similarly, the kernel of the train control problem is the transmission to the train of an indication of conditions in one or more blocks ahead. Given an indication on the train capable of controlling a relay, almost any desired cycle of automatic operation can be established to control the train. The principal problem beyond the relay is to determine what operations are desired.

Before discussing any specific solution of the train control problem, it will be well to examine briefly some of the requirements or desiderata which constitute the conditions of the problem.

Desired Characteristics

1. The primary function of automatic train control is, of course, to stop the train before it enters upon unsafe territory. But it is not necessary or desirable that it should interfere with manual control by the engineer, so long as that conforms to the requirements of safety. To substitute even a very perfect mechanical safeguard for human vigilance would be, to say the least, a questionable gain. Perhaps the mechanical device would respond to the foreseen conditions for which it was designed with more than human certainty; but it could not act intelligently in response to unforeseen conditions. The real gain in safety is to be made by reinforcing the vigilance of the engineer, not by supplanting it. With an automatic control, acting as a second line of defense behind the engineer we have two independent and successive safeguards. Either one may fail, and doubtless will on rare occasions; but the chance that both will fail simultaneously is exceedingly remote.

The automatic apparatus, therefore, should not relieve the engineer of complete responsibility for the safe operation of the train. It should act as a continuous check on the proper exercise of that control, intervening to stop the trains automatically only after the engineer has had ample opportunity to act, and has failed. There is evidence to show that automatic control thus applied, tends to increase, and not relax, the vigilance of the engineer, because the automatic application of the brakes acts as an immediate tell tale if he ever passes a danger signal. It may be desirable

as an aid to discipline to have the apparatus record each automatic brake application or preserve some evidence of it in the way of broken seals or the like.

2. The existing fixed signal systems have been developed to a very high degree of reliability in the course of a good many years. Prudence would dictate that the principles and practises which experience has shown to be safe for fixed signals should be followed so far as they are applicable in the installation of automatic control. The most fundamental of these practises is the so-called "closed circuit" rule, which requires that every "clear" or "proceed" indication be made dependent on the integrity of energized closed circuits, so that any interruption of the circuits or of the power supply will result in a danger indication. In practise, the rule is construed more broadly than this literal interpretation. Not only circuits, but every element of the system is so arranged that it is predisposed to the position or condition corresponding to a danger indication, and will return to that condition automatically upon failure of any part. In the construction of each element every precaution is taken to reduce to a minimum the chance that friction, insufficient clearance, residual magnetism, sticking of contacts or any other cause will bring about a failure to return to the danger indication, when de-energized. It is chiefly due to the rigid application of this rule that such failures as occur in signal systems are almost invariably failures on the safe side—false indications of danger, rather than false indications of safety.

3. Obviously the apparatus should be designed to stand the severe conditions of shock, dirt, weather, etc. that are incident to railway operation, and should not be put out of action by any weather conditions that permit trains to run.

4. The train control devices should not increase the hazards of operation in any respect. They should be free from insecure or dangerous parts, and in particular they should not impair the protection given by existing signal equipment; for regardless of the cab signaling features, that may be incorporated with the automatic control apparatus, railroad officials would be naturally and properly reluctant to abandon the known security they obtain from the existing signals before it has been conclusively established by experience that the new apparatus is at least as reliable as the old. Even if the old apparatus were to be abandoned, it would be highly desirable that the new and the old should cooperate without interference during the transition stage.

5. If possible, it is desirable to avoid conflict with established clearance lines. Where third rail has been installed for traction purposes, it has been necessary to reserve a zone exclusively for the third rail and the contact shoes, excluding from the reserved zone all other parts of equipment and roadway structures. The same thing can be accomplished for train control apparatus if it must be; but it is by no means so simple a matter as it sounds. Bridges, tunnels, station platforms and innumerable roadway structures have been built on the basis of existing clearance lines. Any change in the lines now involves many complications and much expense. The same is true of rolling stock. At least one electrified road has been obliged to gage every foreign freight car accepted for the third rail division, to check its clearance. The most available location for contact devices if used will probably be about the same as that adopted for traction third rails, when not used or reserved for the latter purpose. Third-rail lines will have to find some different location.

6. The automatic control should place no avoidable restriction on the traffic capacity of the road. An effective argument in favor of automatic roadside signals has been the fact that they "keep the trains moving" and increase the traffic capacity. It will be difficult to reconcile the railroads to automatic control if it is found to impede traffic in any noticeable degree. This is an interesting phase of the problem which will be discussed at more length later.

7. It may be desirable in some cases to enforce automatically, local speed restrictions, at curves for example, or heavy down grades, or a uniform speed restriction at all points.

8. The accidents which it is desired to prevent are due in some cases to negligence on the part of the engineers, but in other cases they are due to actual inability to distinguish and interpret the roadside signals correctly, because they are obscured by weather conditions or by steam from other trains or the like. In such cases a clear indication of the safety or danger of the track ahead, given within the engine cab, would enable the engineer himself to avoid danger. Such an indication can be combined with the automatic control, in some cases at least, with comparatively little increase of complication or expense.

9. All of the foregoing has referred primarily to "block signaling" territory, *i. e.*, to main lines between terminals when the sole problem is to space trains at safe intervals; and the recent order of the Interstate Commerce Commission seems to be limited to this territory. But there is another very large portion of the total signaling of railways involved in interlocking plants where switches, derails and the like, as well as signals are controlled by an operator. There is no inherent reason to prevent at least a partial application of automatic control, or cab signals, or both in the interlocking as well as the block signal territory. But the need is less urgent, because speeds are low and signals are observed at shorter range. And the problems involved are more complex, because extensive net works of inter-related tracks are involved, and varied indications of routes and movements are required. Comparatively little thought has thus far been given to automatic train control in interlocking territory.

Methods of Transmitting an Indication to the Train

The simplest system of automatic control and the one that has been used on the largest scale consists of an air valve hung on the car truck near the rail level, and stop arms operated in conjunction with the fixed signals. Whenever a stop signal is displayed, the stop arm is raised into the path of the air valve handle. If the train overruns the stop signal, the valve handle strikes the stop arm, and is knocked open, producing an emergency application of the brakes. This system has given excellent service on the subway and elevated lines where it has been employed but it is not commonly considered adaptable to steam roads in general, because it would be exposed to severe weather conditions mixed equipment, high speed impact, parts dragging on trains, and rougher usage generally than it has been subjected to in existing installations.

A refinement of the mechanical trip idea which has been used and reported to be successful on a number of limited stretches of steam railroads consists essentially of a fixed third rail ramp at each signal location, and a shoe carried by the train. In passing over the ramp the shoe is lifted and operates a brake valve, unless it receives current at the same time from the ramp. But if current is received it acts through a magnetic device to lock out the brake application valve. The ramp is energized by the roadside signal circuits when the signal indicates "proceed" but deenergized when the signal is set for "stop" or "caution". Various control schemes are on the market which have these broad features in common, but differ considerably in construction. In at least one case, provision has been made for giving several distinctive indications by varying the polarity and characteristics of the current supplied to the ramp.

The most fundamental weakness of this type of control, in common with all intermittent indication systems, is that failure to produce any indication necessarily acts as a safety, and not a danger signal. If the absence of an indication were made a danger signal, the trains would receive continuous danger signals from one ramp to the next whether the track ahead was clear or occupied. The train must be permitted to proceed in the absence of any indication between ramps; and if, owing to misadjustment or any other cause, the ramp fails to function, the train can continue past it, regardless of conditions in the block ahead. Nothing happens on the train to indicate that it has passed out of the block to which the last preceding ramp admitted it. The electric circuits in detail can be made conformable to the "closed circuit" rule previously discussed; but the system as a whole cannot operate on the closed circuit principle in its broadest sense, which requires every proceed signal to be given by affirmative action, and every failure of affirmative action to produce a stop signal. Intermittent track circuits in roadside signal practise are a somewhat parallel case. No ingenuity in their arrangement can make them indicate the presence of a train that has somehow got by them and stopped on the dead section between track circuits. In modern systems they have been superseded by continuous track circuits from end to end of the block.

The ramp type of control requires the establishment of special clearance lines, reserving some portion of the roadway cross section exclusively for the ramps and shoes. It seems hardly possible that it can be wholly free from trouble due to snow, sleet, and obstructions in the path of the shoe. On the other hand it is simple, and has behind it the record of more actual use than any other system, except the plain mechanical trip first mentioned. It can undoubtedly be made to give a valuable measure of protection if not the almost absolute protection (within their own scope) that is demanded of roadside signals.

An ingenious departure from the ramp type of control is a stationary flexible metallic brush beside the track, designed to make contact with a fixed shoe on the train. The brush is connected to the rail through a relay contact which is held open to indicate safety. The brake valve is held closed by a locally energized circuit on the locomotive, and released by short circuiting of this circuit in passing over the brush, unless the rail connection to the latter is held open in the relay. Unfortunately this scheme flagrantly violates the "closed circuit" principle in its most essential link, the shunt circuit through the shoe and brush to the rail.

In the permanent magnet induction type of control, large permanent magnets laid between the rails and below the rail level take the place of ramps. An iron core on the locomotive surrounded by a coil takes the place of the contact shoe. Stationary coils are arranged in the region of the magnet poles. When the track is clear they are energized from the roadside signal system and serve substantially to neutralize the field of the permanent magnet. The magnet then has no effect on the train. But when the track is occupied, the stationary coils are dead, and as the train passes over the magnet it induces a momentary current impulse in the coil on the locomotive, which is located to pass over the magnet with a safe clearance. This impulse (acting through a relay) is utilized to cause a brake application.

Aside from the inherent limitations of all intermittent systems three questions suggest themselves, the permanence of the magnets, the degree of accuracy in neutralizing the magnet field, and the effect of passage over the magnet at low speed. The first question can be dismissed when we consider the permanence of magnets in voltmeters and ammeters—not merely approximate constancy such as is required in the track magnets but almost invariable strength over periods of many years. The answer to the second question is not so clear. The balance between the neutralizing coils and the magnet could never be exact; and if the

supply voltage varies as much as is often the case in signal systems, it would be at times extremely rough. The locomotive coil, then, must distinguish not between a magnetic field and no field, but between a field of the normal strength and a reduced field of, for example, one third normal strength. If the apparatus is adjusted not to respond to the reduced field, it would seem that its factor of safety in responding to the normal field would be rather small, judged by signal standards; the more so when it is recalled that the apparatus must take care of a wide variation of speed as well, and some slight variation of air gaps.

Regarding the action of the magnet at low speeds, there will presumably be some minimum, such as four or five miles per hour required to produce an indication. So far as direct danger from collision goes, five miles an hour is equivalent to a stop. But there is a possibility that a train may enter a block at low speed for other reasons than a signal stop. Precautions should be taken to insure that the engineer will not then construe the failure to receive a stop indication as a sign that the track is clear. If he should so construe it, he could accelerate to a dangerous speed within the block.

The permanent magnet system has the marked advantage that it requires no modification of existing roadway and equipment clearance lines; and the further marked advantage that it has no contact parts and therefore no question of insuring contact in unfavorable weather conditions.

A very simple and ingenious modification of the permanent magnet scheme has a laminated iron core in place of the permanent magnet, with a corresponding core and coil on the locomotive. A winding on the track core is short-circuited through a signal relay when the track is clear, and open when the track is occupied. The locomotive coil is continuously energized by a battery. When the track coil is short circuited it serves to choke back any magnetic impulse in its core (like a short-circuited transformer winding). Under this condition passage over the track element produces no considerable change in the locomotive circuit. But when the track coil is open, the magnetic surge in the track element as the energized locomotive element passes over it induces in the latter an inductive kick which results in a brake application. The advantages and disadvantages of this scheme are identical in many respects with the advantages and disadvantages of the permanent magnet arrangement. It would seem to have some advantage over the latter in respect to simplicity and perhaps a material advantage in the fact that its neutralizing circuit is entirely independent of variations in the voltage of the roadside signal system.

An entirely different system of control is the so-called "continuous induction" system. In this case the indicating energy for the locomotive is supplied directly to the rails of the track circuit in the form of alternating current, and collected inductively on the locomotive either by a coil located ahead of the leading wheels and surrounding a portion of the alternating field produced by the rails themselves, or by a small transformer surrounding the leading axle which acts as a single turn primary for the transformer. Detecting apparatus energized by the current induced in the locomotive circuit controls the application of the brakes or the indications of cab signals. When the track ahead is clear, the detecting apparatus is continuously energized and maintains the proceed indication on the locomotive. But when the track is occupied, or when the indicating current supply fails for any other reason, the locomotive apparatus reverts to its deenergized condition and a brake application results. The detecting circuit and apparatus on the train correspond exactly to the track circuit relay in roadside signal systems.

A train in a block automatically maintains a stop indication behind it in the same block by short circuiting the track circuit. But in order to stop a following train before it enters the block, it is necessary to carry the stop indication back to the next section in the rear. Several circuit arrangements which accomplish this are available, but none which utilizes the existing track circuits where roadside signals are installed without some additions. If desired, it is possible to give several distinctive indications on the train by varying the characteristics of current supplied to the track, or by superposing currents of different characteristics. The electrical efficiency of power transmission from the point of supply to the train is exceedingly low. The total energy input is the power consumed in a short-circuited rail circuit which may be several thousand feet long, while the energy collected on the train corresponds at most to the loss in a few feet of the rail circuit. In order to control the train without excessive power consumption in the track circuit a high degree of sensitiveness is necessary in the receiving apparatus on the train. The required sensitiveness is secured without sacrifice of reliability by the use of a vacuum tube amplifier.

The chief defects of the continuous induction system are the necessity of modifying existing track circuits (but without detriment to the roadside signals which they control) and the requirement of exceptionally sensitive receiving apparatus on the train. The outstanding advantage is a degree of safety superior to anything attainable with any intermittent system, and fully equivalent to the continuous track circuit as used for the control of roadside signals. The system is, in fact, merely an adaptation of the standard continuous track circuit to the conditions introduced by placing the relay on the train instead of beside the track. And it is superior to the stationary continuous track circuit in that its indications are immediately effective on the train when a dangerous condition arises, while the indications of a stationary signal even when perfectly observed and acted on are not available until the train comes within view of the next signal. An incidental

advantage is adaptability to the exercise of any desired control or signaling functions on the train by the use of distinctive indications from the track. In particular it is perhaps the only one of the systems enumerated which is capable of giving adequate block signal protection on the train without the use of roadside signals. As an accessory to roadside signals it is unlikely that it can ever be the cheapest system. If it is selected it will be on grounds of superior protection. But as a substitute for roadside signaling, it would not be surprising if it should prove the cheapest as well.

A very large number of other train control schemes of various degrees of merit has been proposed; but the bulk of the systems now being actively advocated falls within one or another of the three classes outlined above; *i.e.*, intermittent control by mechanical and electric contact, intermittent control by electromagnetic induction, or continuous control by induction from the track circuit.

Controlled Functions

Thus far we have considered chiefly the means by which a controlling indication is transmitted to the train; but with any of the systems mentioned there are varied possibilities as regards the kind of control to be exercised after the indication has been received. Discussion of these possibilities will be facilitated if we consider for a moment the conditions that exist in an ordinary block signal system with roadside signals.

In Fig. 1 is indicated a stretch of track protected by semaphores 1, 2, 3, 4, 5. The track from 2 to 1 being clear, signal arm 2 is vertical indicating "proceed". Just ahead of the signal 3 is a standing train. This arm is therefore horizontal, indicating "Stop and proceed under control prepared to stop short of an obstruction in the block". Obviously it is useless to display a stop signal unless the signal can be observed in time to stop the train short of the danger which it announces; *i. e.*, in the case illustrated, at the signal itself. Hence

Fig. 1

the next signal in the rear, (No. 4), is set at 45 degrees indicating "Approach next signal prepared to stop." The first clear, or "proceed" signal in the rear is No. 5, two full blocks behind the obstruction, and this is the closest spacing on which trains can follow one another while running under full-speed signals. The length of the blocks may be two or three miles or more; but when signals are located for the maximum safe traffic it is made about equal to the braking distance for the fastest trains. Trains operating under full-speed signals are then separated by twice the safe braking distance or more.

If an intermediate signal is placed between each two signals of Fig. 1 with overlapping control, so that the caution indication from signal No. 3 extends back to signal No. 4 as before, we get the arrangement shown in Fig. 2, with the clear signal advanced from No. 5 to No. 4A and the minimum full-speed spacing reduced to 1½ times the maximum braking distance. By further subdivision of blocks with overlapping control the spacing could theoretically be still further reduced, with the actual distance inherently necessary for safety as a limit; but in practise the number of signals required would soon become prohibitive. If each caution signal is further made to indicate the speed corresponding to the braking distance between it and the stop signal ahead, slower moving trains can close up to a shorter spacing corresponding in each case to the safe braking distance for the speed at which the train is moving.

Fig. 2

If automatic control is applied to the signal layout shown in Fig. 1, it must take effect at the caution signal No. 4. It would do no good to apply the brakes at the stop signal No. 3, directly behind the standing train. But before reaching the signal No. 4 the engineer has had no intimation that he is required to stop; nor do the present operating rules require him to apply brakes at the caution signal. The present practise without automatic control is to apply the brakes only as required to stop the train at the signal No. 3. A train running at moderate speed may traverse half the length of the caution block or more before a brake application is necessary. An unconditional automatic brake application at the signal No. 4 would thus take the control out of the engineer's hands without previous warning, while he is still operating it in accordance with safe practise. This violates the principle that the engineer must retain full responsibility so long as he conforms to the signal indications. Two alternatives, then, are open. Either the signal No. 4 must be made a second stop signal with a caution indication at the preceding signal No. 5, as shown in Fig. 3, or the automatic action at the signal No. 4 must be made dependent on the action taken by the engineer at the same point or beyond.

In the former case it is evident that the minimum headway for full-speed signal indications is increased from two blocks to three, and the potential traffic capacity of the track is correspondingly reduced. But it should be noted that the traffic capacity of this particular section may still exceed the limit established for the whole operating division by conditions other than headway on the main line. It may easily happen in some cases that the traffic restriction here referred to would not in practise reduce the number of trains which can be operated over the whole division. In this connection it is interesting to note that extremely heavy traffic was operated for years in the New York

subway system under exactly the conditions described; and when the growth of traffic demanded increased capacity, the need was met by improved air brakes which reduced the braking distance, and by special signaling in the station approaches (which were the actual limitation on track capacity) to permit closing in of trains at reduced speed.

The second alternative mentioned was to cause a conditional instead of an unconditional brake application at the caution signal. Several methods of accomplishing this conditional control are proposed.

The simplest of these is a cut-out under the engineer's control or the joint control of the engineer and fireman. If the caution signal is acknowledged while passing it, by operating the cut-out, the train proceeds under manual control without interference. In other words instead of actually enforcing train operation in conformity to the signal indications, acknowledgment of caution signals is enforced, on the theory that an engineer sufficiently attentive to acknowledge the signals can be depended on to take the necessary action when required. But acknowledgment of a signal does not absolutely assure that it has been correctly interpreted. It would be possible for the engineer to operate his cut-out at every signal, regardless of its indication.

Another proposal involves a modification of the present operating rules. A definite speed limit is established for the caution block, and the engineer on passing a caution signal is required to reduce his speed immediately to the prescribed limits. If he makes a sufficient brake application for this purpose promptly at the caution signal, the automatic control apparatus does not interfere; but if he fails, the automatic control does it for him. In one system a second indication for full stop is provided at a sufficient distance from the stop signal to bring the train to rest from the speed prescribed for the caution block. This plan restricts train movement in so far as it enforces a speed reduction earlier than safety and the present operating rules require. In the case of long blocks this may become a substantial restriction. The scheme appears to be safe in principle.

Still another method is to hold the automatic brake application in suspense from the time the caution indication is received to the time the brakes must be applied to stop at the stop signal. The actual time of application varies with the speed of the train, just as it does in manual control. In other words, the point of brake application varies in accordance with the curve of braking distances for various speeds. For convenience we can designate this as the "braking curve" type of speed control. Several methods of determining the point of brake application have been worked out. In one of these the caution indication is repeated at diminishing intervals as the stop signal is approached, the distance between each two successive indications corresponding to a certain time interval when the train is moving at the greatest speed permissible at that location. Two indications received in less than the established time interval show that the speed exceeds the limit set in the spacing of the indication points, and cause an automatic brake application. This principle has been applied for establishing speed limits at certain points in the New York subway system. The successive indications in that case took the form of roadside signals located at short intervals, with an automatic stop arm associated with each signal. The time intervals were measured by the relays which controlled the signals.

Another method involves a cam driven from an axle of the train. As the train proceeds through the caution block the cam establishes diminishing speed limits, and a speed-indicating element causes the brake application whenever the actual speed exceeds the limit established by the cam.

Still another method comprises a flywheel retarded periodically from a speed proportional to that of the train. The angular movement of the flywheel during retardation is a measure of the distance required to arrest the train; and when the distance remaining to the stop signal has been reduced to the indicated braking distance, the brakes are automatically applied.

All speed controls of the "braking curve" type require the automatic caution indication to be effective at a uniform distance from all stop signals. This type in common with the type based on limited speed in the caution block restricts train movement in one respect. In manual operation it often happens that an engineer after passing a caution signal finds the succeeding signal at caution instead of stop when it comes in view. The train which caused the original stop and caution signals has passed on to the second block ahead. Under these circumstances he accelerates again, and prepares to stop at the second signal. But in the case of any automatic cycle initiated by an intermittent indication from the track, the cycle would continue automatically to completion. The train would stop, and then proceed in accordance with the signal received at the next indicating point.

In connection with Fig. 2 it was shown that the headway of trains under manual control can be substantially reduced by subdividing the signal spacing determined by the braking distance of the fastest trains. The same thing applies with equal force to automatic control; and in fact involves less added complication than in the case of roadway signals; for the semaphores themselves, with their supporting masts or bridges are a major item in the latter case. Multiplication of signals would soon become prohibitive. In the case of automatic control on the other hand the increased equipment consists chiefly in the added circuits, with their associated relays, etc. Furthermore the number of speed indications which can be intelligibly given by semaphores is limited, while any reasonable number of indications can be provided for in the locomotive cab.

Fig. 4 illustrates a case in which the maximum braking distance is subdivided into three indicating sections. In each section the speed is limited to a value which permits of stopping the train between the exit of that section and the entrance to the occupied block. At the entrance to each section an unconditional stop is assumed for any train running at a higher speed than the limit effective in that section. A warning (corresponding to a caution signal) is therefore necessary at the entrance to the preceding section. The warning signals are represented in Fig. 4 by circles inclosing the speed to be indicated. They may be roadside signals or signals displayed in the cab. The example illustrated gives a minimum headway of $1\frac{2}{3}$ blocks for operation under full-speed signals, as compared with

Fig. 3

two blocks for manual control in Fig. 1, and three blocks for unconditional stop with one block overlap in Fig. 3, with shorter headway for lower speeds. Theoretically, the headway could be further reduced by one-third block by combining the subdivided blocks with any of the plans already discussed for qualified control initiated at the caution signal.

To illustrate the relation of the various control cycles here discussed to headway and traffic capacity, the headway attainable under certain assumed conditions has been tabulated in Fig. 5. Headway is expressed in seconds rather than feet in order to show more directly the bearing on the potential traffic capacity of the track, in trains past a given point per hour. The conditions assumed are:

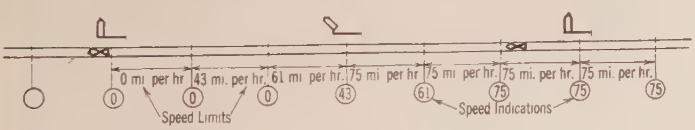


Fig. 4

Time counted from the head of one train to the head of the following train.

Train length, 1000 ft.

Maximum speed 75 mi. per hr.

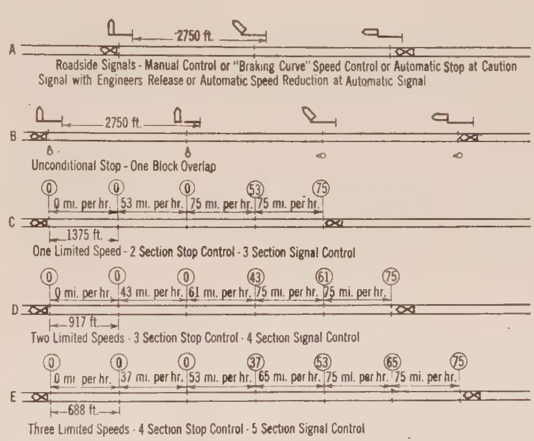
Train speeds 40, 60 and 75 mi. per hr.

Retardation 1. 5 mi. per hr. per second.

No allowance for time consumed in operation of semaphore signals.

The following train is assumed to approach each signal just as it assumes the permissive indication for the speed at which the train is running. The permissive indication for manual operation is considered to be the "proceed" signal at all speeds; for although it is permissible to pass the caution signal at speed, it is not permissible to maintain the speed throughout the block, unless the following signal is visible before the time comes to apply the brakes; and the range of visibility varies with location and weather. In most cases of manual operation at speeds below the maximum, a smaller headway than the table shows can be maintained by running under caution signals. The same is true of "condition" control by continuous induction without reservation as to visibility.

Line *A* refers to manual operation with signals spaced at the maximum braking distance. The same headway is required for any of the "conditional stop" arrangements with the same signal spacing and the stop indication at the caution signal. *B*, *C*, *D*, and *E* are for one section overlap with an unconditional stop effective at the rear stop signal and the necessary caution signals back of the stop. They show respectively one, two three and four automatic stop sections in the length of the maximum braking distance. With the subdivided blocks, progressive speed limits are



	Minimum Headway in Seconds for Sustained Speeds		
	40 mi per hr.	60 mi. per hr.	75 mi. per hr.
A	111	74	59
B	157	105	84
C	87	74	59
D	64	53	51
E	64	50	47

Fig. 5

provided. Line *C* with the braking distance subdivided in two sections gives the same headway at the higher speeds as manual control without overlap. The smaller subdivisions permit reduced headway. Lines *B*, *C*, *D* and *E* respectively require two, three four and five distinctive control and signal indications.

Conclusions

The substance of the matter seems to be that practical means are available for any kind of control likely to be required in automatic territory, though only a few of the arrangements described have been worked out in actual railroad service on any considerable scale. From a safety standpoint the arrangement that most clearly conforms to sound signal practise is perhaps the unconditional stop with an overlap of one control section, whether the control section is the total braking distance as at *B* in Fig. 5, or a subdivision of the braking distance as at *C*, *D* and *E*. This arrangement lends itself readily to any required concentration of traffic

but it requires more track circuit and control circuit apparatus for equal headway than the conditional stop arrangements installed as shown at *A*.

Comparatively few railroads at the present time have signals spaced for the minimum safe headway, and it is not probable that the maximum possible track capacity will be required on any considerable mileage of the roads equipped. It would seem a natural development to retain the present signal spacing on the major portions of the roads, either with unconditional stops and one block overlap, or with conditional stops effective at the caution signal; and to provide the needed capacity at points of special congestion by relocation of signals when they are not now spaced at the minimum permissible distance, or by subdivision of the blocks where signals are already so spaced. Where extensive changes of existing signals are required, it would be worth while to consider whether the same result can be more economically obtained with cab signals.

With automatic control in force, it seems likely that the future trend of signal development will be toward cab signals rather than roadside signals; first because they are inherently capable of giving greater protection, and secondly because they involve less apparatus over and above that required in any case for the automatic control. If this is true, the railroads may find it desirable in making their present automatic control installations to give some consideration to possible future requirements for cab signals.

COLLEGES TO BROADCAST LECTURES

Foreseeing millions of listeners, the bulk of them of college age, the National Radio Chamber of Commerce is developing a plan to establish radio extension courses in American colleges and universities. In radio, education has found a new and powerful ally, says an announcement issued from the Chamber's headquarters, 165 Broadway, New York City.

England and Germany, it was stated, are planning to broadcast university extension courses. "Several prominent institutions of learning in the United States have made a beginning in this direction," the announcement continued, "and their reports of the encouraging success attending their efforts show us that the possibilities of the new method are not underestimated.

"Sixty other educational institutions are broadcasting educational and musical programs, forty-seven of them being colleges and universities. The combined area nominally covered by these institutions has been estimated to be seven or eight times the total area of the United States."

The National Radio Chamber of Commerce, which has set out to end confusion in the radio industry by bringing into harmony all of its instrumentalities, is devising a scheme of practical assistance to educational institutions.

"The importance of radio broadcasting as a means of reaching a large number of listeners in the United States, otherwise inaccessible, is being forced home to us every day," its announcement said. "There are in the United States between a million and a half radio receivers, representing between three and four million radio listeners located within comfortable range of the speaker's voice of one of 600 broadcasting stations, that is stations equipped with send out telephonic communications. These listeners are for the most part youthful—of school and college age. Their number is rapidly increasing and will undoubtedly, within a very few years, total many millions.

"The National Radio Chamber of Commerce appreciates the tremendous potentialities of this new channel of communication in the field of education and desires in some practical way to support colleges and universities in extending their influence through radio extension courses to these listeners, a large proportion of whom would not otherwise be reached.

"England and Germany have quickly grasped the significance of radio telephony as a means of educational contact and preparations are being made to broadcast university extension courses in those countries.

"Extension lectures may be from the college or university without in any way interfering with the local audience within the school. It is not now necessary that the school have its own broadcasting station; a powerful central station nearby connected therewith by the microphone in the lecture room may be used. In some instances the lectures are being followed up by questionnaires and suggested reading, which are mailed to the listeners upon request, and by examination sheets following at the end of the course.

"Pioneers are already active in this field, and the situation seems to indicate both individual and concerted action. There are, however, a great many intricate problems connected with the subject of broadcasting, which the National Radio Chamber of Commerce hopes to see solved within a comparatively short time. These problems have an intimate connection with the success of any considerable program of educational extension by radio."

Kenneth P. Gregg, one of the engineers and managers of the National Chamber, said the Chamber was collecting a large amount of data to place at the disposal of educational institutions. The aim of the Chamber, it was stated, "is to see that radio broadcasting assumes, in the course of its evolution, a sound economic position of greatest possible usefulness."

Prof. Michael I. Pupin of Columbia University, thinks that radio's greatest field of usefulness will be in popular education. The "craze" stage is passing, and the stage of real utility is approaching, according to Prof. Pupin, who predicts that through radio education will be carried to multitudes of working men and women who otherwise would be cut off from the sources of higher learning.

Balance Methods in Alternating Current Measurement

BY PERRY A. BORDEN

Member A. I. E. E.

Hydro-Electric Power Commission Laboratories, Toronto, Ont.

THE advantages of opposition or balance methods of measurement, except where speed is the primary requisite, are too well known to require elaboration in this paper. They may be used, not only for measurements where extreme precision is required, but also in the determination of electrical quantities which are too minute to operate instruments of the direct-deflecting type, or which emanate from sources where conditions would be disturbed by the introduction of such instruments. Since alternating-current instruments are of inherently lower sensitivity than those for direct current, it follows that the need for opposition methods of test are more pressing here than where meters of high sensitivity are available.

In alternating-current work, the use of opposition methods has been seriously handicapped by two conditions which for direct current do not apply. These are, first, the difficulty of obtaining a suitable opposing current or electromotive force; and, secondly, that of detecting a condition of true balance between the opposing quantities. While these troubles have been fairly well overcome for tests where the most perfect conditions of wave form, frequency regulation and freedom from outside disturbances are available, the expense of the equipment, and the delicate conditions of operation seriously interfere with the use of these methods in ordinary commercial laboratories and testing shops. The value of opposition methods in alternating-current work is probably best exemplified in the Drysdale[1] potentiometer; but, as is well known by all who have studied this device, any of the interfering conditions mentioned above will seriously limit its usefulness.

The methods of test described below are not in any sense those of the extreme precision of the standardizing laboratory; but are intended to illustrate how, with comparatively simple and common instruments, and apparatus which can be built up by any good mechanic there may be made measurements on alternating-current quantities of small value or of poor regulation which will be far more satisfactory than those directly obtainable with indicating instruments.

Opposition methods of measurements may be classified under the two heads of "null" and "semi-null," or "balance" and "balance-deflection." *Null* methods are those in which the quantity to be measured is opposed by a similar quantity both adjustable and measurable, the difference reduced to zero, and the measurement performed upon the latter quantity. In *semi-null* measurements, the opposing quantity, while measurable, is not of necessity adjustable. The final measurement is performed upon that quantity which represents the difference between the other two. Referring to Fig. 1, if $O\,A$ represents a vector quantity which it is desired to measure, and $O\,B$ be a vector of adjustable and measurable magnitude and phase position, the null method of measurement would consist in reducing $A\,B$ to zero and measuring $O\,B$. The semi-null method would call for a measurement of $A\,B$, which, combined with $O\,B$ would make possible the derivation of the value and position of $O\,A$. Each of these classes of measurement has an important place in alternating-current work; and in some cases they may be combined in the one test. In this discussion they will, as far as possible, be studied separately, the null method receiving the first consideration.

FIG. 1

Null Methods

There are three requisites to the use of the null method in electrical measurement, first, the opposing quantity, against which is balanced the quantity under investigation; second, a means of detecting when a condition of balance exists; and, third, a means of measuring the opposing quantity as to magnitude, and possibly as to phase position. These three requisites are dealt with in order.

Source of Opposing Current or E. M. F.

In direct-current null method work, (probably best exemplified in the simple potentiometer), it is necessary only to oppose the current or voltage being measured by a similar quantity derived from a separate battery and adjust the magnitude of the latter quantity, until a balance is obtained. With alternating currents it is necessary to drive the opposing force from a source synchronous with the quantity under investigation, and to provide means whereby not only the magnitude but the phase position may be adjusted with accuracy. There are several ways in which this may be accomplished. It may be done by a combination of rheostats fed from a polyphase source or by a similar combination of tapped transformers, or by the use of inductances and capacities but these schemes are awkward and do not lend themselves to fine adjustment unless elaborate interconnections are used. Probably the best method lies in the use of a separate alternator driven synchronously with the supply and capable of having its field structure shifted about the armature. Such machines, however, are not very common, and unless one has the facilities of the electrical manufacturing plant at his dis-

[1]See Bibliography.

To be presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 14-17, 1923.

posal, are likely to be disproportionately expensive. The most workable method is in the use of the induction type of phase shifting transformer. This is similar in construction to the feeder voltage regulator, being built like an induction motor with a wound rotor, having its stator energized from a polyphase source to produce a rotating field. The secondary winding may be either single-phase or polyphase; and the rotor is adjustable to any desired position. Phase-shifting transformers manufactured especially for the purpose are available, and are made with a smooth core, practically eliminating wave distortion. The apparatus used by the writer, however, was constructed from a small three-phase motor, having the rotor bars removed and replaced by a well distributed single winding, and the rotor fitted with a worm wheel and graduated dial. While a slight wave distortion was visible when the primary and secondary voltages were opposed and an oscillogram made of the residual voltage, this was not found to affect results to any appreciable extent; and while the graduated dial was used merely as an indicator of the rotor position, its readings were usually found to be in remarkable agreement with phase positions as determined by precise methods. By means of a small auto-transformer and a potentiometer arrangement of resistances supplied from the secondary of the phase shifter it was possible to obtain voltages and currents which could be adjusted to a very nice degree of precision. The general arrangement of the phase shifter is shown in the wiring diagrams illustrated in Figs. 4 and 5.

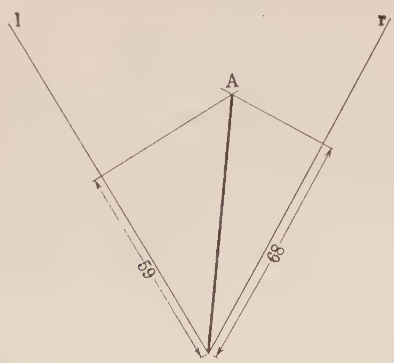


Fig. 2

Determination of Balance

Probably the greatest drawback in alternating-current methods of potentiometery, and null methods in general has been the determination of a condition of balance. For direct current there are available numerous galvanometers and detectors, the most popular doubtless being the D'Arsonval galvanometer. Failing this, it has been possible to use the telephone with some form of interrupter introduced into its circuit. On alternating current we have not the same flexibility of choice. High sensitivity instruments having permanent magnets are, of course, not directly applicable; and instruments of the moving iron or single-circuit electrodynamic type, operating on a law of squares, lose their sensitivity as the zero point of the scale is approached. The telephone may, of course, be used; but as it has a low sensitivity on commercial frequencies, it is almost as necessary to use an interrupter as on direct currents. To this difficulty is added the effect of harmonics; for, while the fundamental may be balanced out, the unbalanced harmonics, to which the telephone is much more sensitive than to the fundamental, have a very disturbing effect. A galvanometer of the permanent magnet type may be used, the balancing current being led to it through a synchronous contactor; and while in many tests this arrangement has proved most satisfactory, there remains the drawback that if a complete balance is desired, observations must be made with more than one position of the contacting points relative to the field of the driving motor. Similarly, a detector of the dynamometer type with a separately excited field may be used, the excitation being obtainable from two out-of-phase sources, synchronous with the supply. With either of these detectors it is possible to obtain a balance by alternately using the two brush positions, or field excitations, as the case may be; and balancing, first on one and then on the other, until no deflection is obtained with either, which, of course, is the condition of true balance. This method, while quite workable, has been found slow and cumbersome, as well as very confusing unless extreme care is exercised in the sequence of adjustments. There remains, of course, the vibration galvanometer, which is undoubtedly the most sensitive detector we have for this work. It requires, however, a closely regulated frequency, which is often not obtainable; and it must be carefully protected from outside mechanical vibrations. These features seriously limit its use except under the most exacting conditions.

As an outcome of these methods of detection, there has been developed by the writer a system whereby the defection of balance is greatly facilitated; and this, to borrow the terminology of the radio engineer, may be termed the "heterodyne" method; and the detector the "heterogalvanometer" or "heterodynamometer," according to the equipment used. This consists, in brief, in replacing the synchronous contactor which would ordinarily be used with the D'Arsonval galvanometer by an asynchronous contactor, or the synchronous field of the electrodynamic instrument by a field derived from a source slightly differing in frequency from the supply. If a galvanometer is being used, the change to a "heterogalvanometer" is made by driving the contactor at an asynchronous velocity, when the galvanometer will oscillate with a periodicity corresponding to the difference between the frequency of the supply and that represented by the speed of the contactor. It is at once evident that this may be very simply accomplished by direct attachment of the con-

tactor to the shaft of an induction motor driven from the supply, when the oscillations of the detector will represent the slip of the motor. In balancing, it then becomes only necessary to adjust until the oscillations of the detector cease, when it is known that the current flowing in its coil has a value of zero, and that consequently there is a true balance between the opposed quantities. If an electrodynamometer is to be used as a "heterodynamometer," the field is excited from a separate source, having a frequency differing slightly from that of the supply. If a separate motor generator is available this may be very conveniently done; and by slight adjustments of its frequency, an excellent control obtained of the period of swing of the detector. If an alternator is not at hand, a suitable off-frequency supply may be obtained by passing direct current through a "rectifying" commutator attached to the shaft of an induction motor. All these methods have been used by the writer with good success. Excellent results have been obtained by the heterogalvanometer method, using a Leeds and Northrup portable indicating galvanometer as a detector; while for the heterodynamometer method, use was made of a re-modelled Weston Model 18 voltmeter. In this instrument the fixed and movable circuits were separated and brought out to different sets of terminals, the windings being left unchanged, with the exception of an auxiliary field circuit of a comparatively few turns, used for "feeling out" conditions. The zero point was brought to the center of the scale, and a new calibration made, using a constant field and a varied current in the moving coil.

Measuring and Locating the Opposing Quantity

When a condition of balance between the measured and opposing quantities has been obtained, there remains the problem of determining the magnitude, and possibly the phase position of the latter, from which to derive the former. If the quantity under measurement be a current, and its value be beyond the range of ordinary indicating instruments, it is necessary to make use of a three-coil transformer, which is described under the head of "Measurement of Current." If a small voltage is being investigated, a potentiometer arrangement is made up, and a measurable voltage obtained. These quantities would then be determined as to magnitude with direct indicating instruments of any reliable type. As it is frequently desirable to find the vector position of the current or voltage, as well as its magnitude, there is described below a method developed by Mr. H. S. Baker, and capable of almost unlimited application.

Assuming a sinusoidal wave and a constant voltage, the indication of a wattmeter or of any instrument of the electrodynamic type is in proportion to the projection of the vector representing the current in one circuit upon that representing the field produced by the other; or, to be more lucid, though perhaps not so precise, the reading of a wattmeter represents the projection of the current upon the voltage. Conversely, the locus of the end of the current vector will be a perpendicular to the voltage vector drawn through a point on the latter representing, in its distance from the common origin, the indication of the instrument. Now, if an equal voltage of different phase position be applied to the instrument, the current remaining as before, the end of the current vector will lie also on a perpendicular drawn through the new voltage vector at a point representing the new indication. Since these results are obtained with the one current, it follows that the intersection of the perpendiculars locates the end of the current vector, thus definitely fixing the position of the current in relation to the two voltages. In a similar way any number of current vectors may be plotted by projecting them against the same reference voltages. This method of plotting vectors is illustrated in Fig. 2. The vectors "l," (left), and "r," (right), are the two

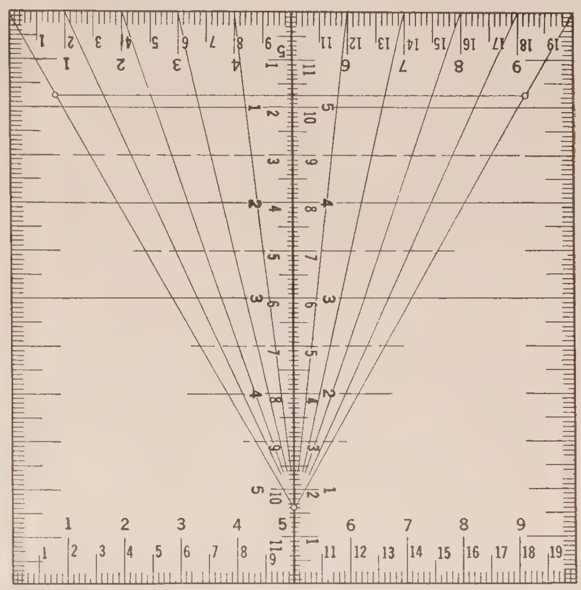


Fig. 3—Transparent Scale Used in Plotting Vectors

reference vectors, representing the field excitations which are used in the wattmeter or dynamometer. The indications of the instrument as read with a single current projected against first one and then the other of these are scaled off along the respective vectors. The position of the end of the current vector will then lie at the intersection of perpendiculars drawn through these points. Suppose the readings with the left and right hand vectors had been 59 and 68 respectively; the procedure would be as follows: On vector l, using any convenient scale, measure off a distance of 59 units, and erect a perpendicular. On vector r, using the same scale measure off 68, and erect a perpendicular. The intersection of these perpendiculars gives the point A, the end of the current vector. In a similar way any number of current vectors may be plotted by projecting them in a dynamometer, against the same reference vectors.

While the above is taken as referring to the location of current vectors, it will be seen that with two equal current vectors at a fixed angle it is equally easy to locate voltage vectors. The reference vectors may be at any convenient angle; but practical considerations would usually make this angle sixty degrees, as derived from two phases of a three-phase system. The plotting of vectors by this system is facilitated by the use of a transparent scale similar to that shown in Fig. 3.

Having described the three elements of the test—the source of opposing current, the balance detector, and the plotting of the vectors,—we may now proceed to the discussion of some applications of the methods in actual work.

Measurement of Current

The general diagram of connections for current measurement is shown in Fig. 4. When the current investigated is not of a magnitude conveniently measurable on the indicating instruments at hand, use is made of a three-coil transformer or "test ring." Great flexibility of design is here possible, almost any

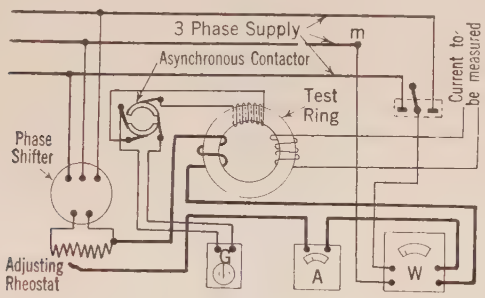


Fig. 4—Measuring Small Current, Using "Heterogalvanometer" Detector

small transformer with three separate windings about its core being adaptable to the work. Excellent satisfaction has been obtained by the writer by making use of a "Baker test ring," designed for current transformer ratio and phase-angle measurements. This ring carries three windings, which may be referred to as "primary," "secondary," and "tertiary," though here these terms are not in strictly correct usage. As employed in these tests, the primary consists of two turns wound on the ring and carrying the opposition current derived from the phase-shifter. The secondary winding, set to 200 turns and carries the current which was under measurement. The tertiary winding of some 7000 turns is led to the detector operating as a heterogalvanometer. The opposing current being adjusted until the detector indicates a condition of balance, it follows that the flux in the magnetic circuit of the ring has a value of zero; and hence that the ampere-turns of the primary and secondary windings are equal and opposite. Under these conditions the transformer is operating at its true turn-ratio; so that the measured current will be a definite and known multiple of the opposing current, and in exact phase opposition. The opposing current then being measured as to magnitude and vector location, the same information is obtainable in regard to the measured current by applying the turn ratio of the transformer. With the set-up described above, the writer has been able to measure and definitely locate currents of the order of one tenth of a milliampere; and there does not appear to be any obstacle

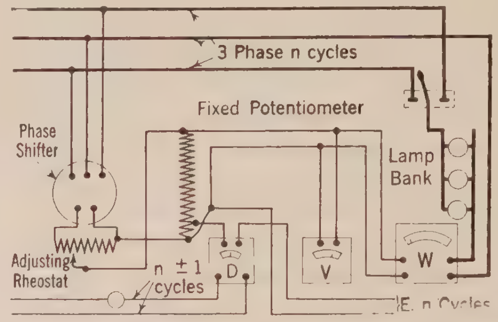


Fig. 5—Measuring Small Voltage, Using "Heterogalvanometer" Detector

in the path of far greater refinement if found desirable. The same general scheme, with a reversal of ratio arrangement would be suitable for measurement of very large currents. In cases where the current is of a magnitude measurable by instruments at hand, the test ring may be omitted and a direct opposition connection used. A cut of the actual apparatus used is shown in Fig. 7.

Measurement of Voltage

The connections for voltage measurement are shown in Fig. 5. It will be seen that, with exception of the

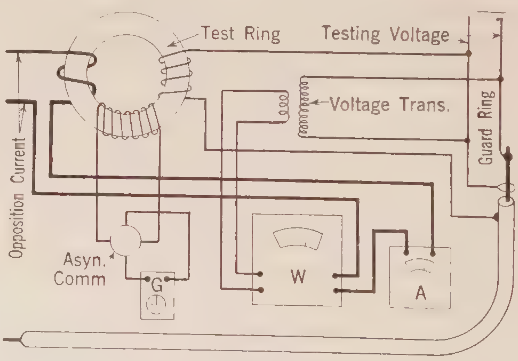


Fig. 6—Simplified Diagram Showing Measurement of Dielectric Loss in Cable

replacement of the test ring by a non-inductive tapped resistance of the potentiometer type, the arrangement is practically the same as that for the determination of current. If a non-inductive adjustable potentiometer is at hand, it may be possible to apply the true potentiometer principle to the test; when the method closely approaches the system developed by Dr. Drysdale.[2]

[2]See Bibliography.

Measurement of Power

The application of the null method to measurement of power suggests itself, and requires little explanation. In the measurement of small wattages or of power in circuits which would be disturbed by the introduction of instruments, it is seldom that both current and voltage would require a null method of measurement. Such being the case, the directly measurable quantity is led in the usual way to a suitable wattmeter, and the other quantity transferred by the null method to the instrument; when the proper ratios being taken into

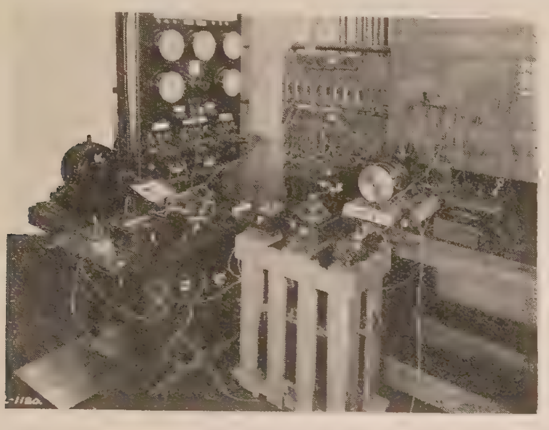


Fig. 7—Set-up for Measuring Transformer Exciting Current at 1/150 Voltage

A: Transformer under test, in shipping crate; B: Phase-shifter; C: Adjusting rheostat; D: Three-coil transformer, or "test-ring," with two turns in primary; E: Asynchronous contactor; F: Ayrton shunt; G: Portable indicating galvonometer used as a "heterogalvanometer"; H: Standard non-inductive resistance, used in examining opposing current; I, J: Ammeter and wattmeter used in examining opposing current; K: Portable motor-generator set, used with "heterodynamometer" method.

consideration, the wattmeter will indicate the actual power in the circuit. Here, of course, if the power be at low power factor, as is frequently the case, careful allowance must be made for phase angle of the instrument transformer (if any) used in the direct measurement. A system of connections for power measurement is shown in Fig. 6.

Determination of Inductance and Capacity

Inductance measurements may be made by plotting the voltage across the circuit investigated, and comparing it with the drop across a non-inductive resistance carrying the same current. This will give the phase angle, from which the inductance may readily be derived. In an exactly similar way capacity may be determined. If more convenient, the voltage may be taken as the fixed quantity, and measurement made upon the currents flowing through the circuits.

Semi-Null Methods

While semi-null methods of opposition are commonly used in alternating-current measurement, it is thought well to briefly recapitulate some of these applications, more with a view to collecting the matter under one head, than with any object of introducing new material.

Transformer Ratios

A considerable number of methods of determining instrument transformer ratios by opposition methods are in vogue; and the principal differences among these lie in the way of dealing with the differential current or voltage representing the amount by which the transformer departs from its intended ratio. While it will at once be evident that the null methods described above may be applied in the study of these small vector differences, it is frequently possible to dispense with this refinement; and, by means of the system of reference vectors, directly examine the differential current or voltage, whence may be derived the constants of the transformer.

In testing current transformers with the "Baker test ring,"[3] previously referred to, the primary and secondary currents of the transformer under test are made to circulate in opposition about the ring, (the respective windings having first been set to the nominal ratio of the transformer) and the vector difference of the two sets of ampere-turns as derived from the tertiary winding examined against reference vectors in a dynamometer. By introducing known errors into the turn ratio of the ring, a number of vectors are obtained, from which a diagram may be constructed, giving graphically the constants of the transformer to a high

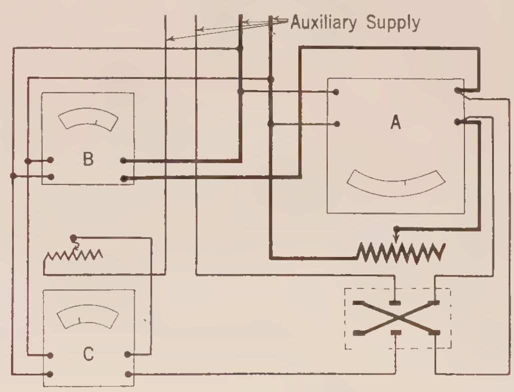


Fig. 8—Connections for Checking Wattmeter by Semi-Null Method

A: Standard Instrument; B: Instrument being checked; C: Low reading instrument, indicating error.

degree of precision. A similar method may be applied to the testing of voltage transformers against a standard potentiometer; but the possible errors due to current flowing in the tap impose limitations which make desirable the use of a null method or the employment of a standard transformer.

Instrument Checks

A method has been published by the writer[4] whereby increased precision in the comparison of indicating instruments with standards is made possible by a semi-

3. See Bibliography.
4. See Bibliography.

null method. This is particularly applicable to wattmeters, but with certain limitations to ammeters and voltmeters also. Here, an auxiliary current is passed through the circuit of one of the instruments under test, as shown in Fig. 8, both instruments thus being brought to an identical reading. This auxiliary current being then measured in an instrument of comparatively high sensitivity, the difference in accuracy of the two instruments under comparison is thus shown in a greatly magnified form.

Efficiency Measurement

A semi-null method of efficiency measurement has been developed and used with considerable success on pieces of apparatus wherein both the input and output are electrical quantities[5]. This can be applied in the case of transformers and some motor-generator sets.

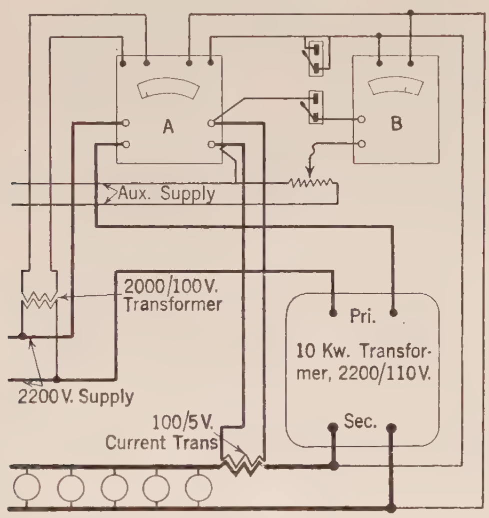


Fig. 9—Determining Transformer Losses by Semi-Null Method

A: Two-element (polyphase) wattmeter; B: Low reading wattmeter, indicating losses.

The system, as illustrated in Fig. 9, consists in passing the input and output in opposite senses through the circuits of a two-element wattmeter such as is commonly used for polyphase measurements, and adding an amount of power derived from a separate source to the output side of the instrument, to balance the two, and bring the wattmeter to zero indication. This comparatively small quantity may then be measured on a separate wattmeter of suitable range, giving a magnified indication of the losses in the apparatus tested.

Conclusions

The tests which have been described above cannot in any sense be said to exhaust the possibilities of opposition methods of measurement as applied in alternating-current work. The instances which have been cited are given as thoroughly practical examples, and as cases which are backed by the author's experience. It is felt that all who have studied this branch of electrical measurement or who are in their work confronted by problems of measurement which seem to surpass the capabilities of the instruments and equipment of the ordinary commercial laboratories will be able to find in this study many helpful suggestions. In the course of the paper, a number of references are made to the investigations and developments of Mr. H. S. Baker of the Ontario Power Company, whose earlier work along the lines here set out has been of inestimable assistance to the writer, and whose inspiration has been a continual incentive to carry the development of balance methods of testing to a further degree of perfection than has heretofore been published; and the writer takes this opportunity to pay a part at least of the debt of gratitude which he owes to Mr. Baker's infinite genius and kind cooperation in the working out of these methods of testing.

Summary

(1) Owing to the comparatively low inherent sensitivity of alternating-current instruments, balance or opposition methods of measurement are more desirable and of wider application in alternating-current testing than in direct-current work.

(2) The application of balance methods to alternating-current tests is a greater problem than in direct-current work, because of the necessity of having to oppose the measured quantity in phase position as well as in magnitude; and because of the difficulty of precisely detecting when a condition of balance is obtained.

(3) A suitable source of current or voltage for opposition tests consists in the phase-shifting transformer, to which is added a potentiometer type of rheostat.

(4) A satisfactory detector is found in the D'Arsonval galvanometer or the electrodynamometer, so arranged that the indicator oscillates at an easily observable periodicity. A condition of balance exists when the oscillations have been reduced to zero.

(5) In current measurement, use is made of a transformer having three windings, the measured and opposing current flowing in two of these windings, and the difference, as derived from the third, reduced to a zero value, when the ratio between the active currents becomes the turn ratio of the transformer. With this arrangement it is equally easy to measure extremely small or extremely large currents.

(6) In voltage measurement a simple potentiometer arrangement of resistance is used, the ratio being set to a suitable value at the beginning of the test.

(7) The opposing current or voltage, after a balance has been obtained, may be measured by indicating instruments, and if desired, its vector position plotted, by

5. See Bibliography.

means of a pair of readings obtained with an instrument of the wattmeter type against two "reference vectors."

(8) Null methods of test may be applied to measurement of quantities of current, voltage or power which are either too small, (and in some cases too large) for instruments of ordinary types, or are derived from sources wherein conditions are so unstable that they would be disturbed by the introduction of these instruments into the circuit.

(9) Semi-null methods, where a complete balance is not obtained, are applicable to transformer ratio measurements, instrument checks and, in some cases, to the measurement of efficiencies.

Bibliography

Agnew, P. G. and Fitch, T. T. The Determination of the Constants of Instrument Transformers. *Bull. Bureau Stds.* P. 281, Vol. VI, 1909.

Agnew P. G. and Silsbee, F. B. The Testing of Instrument Transformers. TRANS. A. I. E. E., June 28, 1912.

Agnew, P. G. A Study of the Current Transformer. *Bull. Bureau of Stds.* P. 423, Vol. VII, 1911.

Baker, H. S. Current-Ratio and Phase-Angle Test of Series Transformers. *Electrical World*, P. 234, Vol. LVII, 1911.

Baker, H. S. Ohmic and Inductive Resistance of Meter-Current Circuits. *Electrical World*, P. 565, Vol. LVIII, 1911.

Baker, H. S. Current Transformer Ratio and Phase-Error by Test-Ring Method. PROC. A. I. E. E., P. 1173, Sept. 1918.

Bennett, Edward. A Milliampere Current Transformer. TRANS. A. I. E. E., P. 571, Vol. XXXIII, 1914.

Borden, Perry A. Method of Ascertaining Error in Indicating Instruments. *Electrical World*, p. 495, Vol. LXVII, 1916.

Borden, Perry A. Determination of Transformer Losses. *Electrical World*, P. 716, Vol. LXVIII, 1916.

Brooks, H. B. A New Potentiometer for the Measurement of Electromotive Force and Current. *Bulletin Bureau Stds.*, P. 225, Vol. II, 1906.

Brooks, H. B. A Deflection Potentiometer for Voltmeter Testing. *Bulletin Bureau Stds.*, P. 275, Vol. IV, 1907-08.

Brooks, H. B. Deflection of Potentiometers for Current and Voltage Measurements. *Bulletin Bureau Stds.*, P. 395, Vol. VIII, 1912.

Brooks, H. B. Design of Deflection Potentiometers. *Bulletin Bureau Stds.*, P. 419, Vol. VIII, 1912.

Campbell, A. On the Measurement of Very Large and Very Small Alternating Currents. *Phil. Mag.* 52, P. 271, 1896.

Cone, D. I. Bridge Methods for Alternating Current Measurements. TRANS. A. I. E. E., P. 1743, Vol. XXXIX, 1920.

Cotton, H. Measuring of Power at Low Power Factors. *Electrician*, P. 554, May 6, 1921.

Craighead, J. R. Potential Transformer Testing. TRANS. A. I. E. E., June 8, Vol. XXXI, 1912.

Dawes, Chester L. Phase-Angle of Current Transformers. TRANS. A. I. E. E., P. 1585, Vol. XXXIV, 1915.

De La Corce, P. Determining Transformation Ratio and Phase-Lag in Current Transformers. *Bulletin de la Soc. Internat des Elect.*, July 1916.

Electrician, Jan. 12, 1917.

Elect. World, P. 327, Vol. LXIX, 1917.

Drysdale, C. V. Measurement of Phase Differences. *Electrician*, Pp. 726 & 782, Vol. LVII, 1906.

Drysdale, C. V. Some Measurements on Phase Displacements in Resistances and Transformers. *Electrician*, P. 160, Vol. LVIII, 1906.

Drysdale, C. V. The Use of the Potentiometer on Alternating Current Circuits. *Phil. Mag.*, P. 402, Vol. XVII, 1909.

Drysdale, C. V. The Alternating Current Potentiometer as a Standard Instrument. *Electrician*, P. 157, Vol. LXXV, 1915.

Drysdale, C. V. Measuring Instruments. *Electrician*, P. 853, Vol. LXXVII, 1916.

Farmer, F. M. Measurement of Power Loss in Dielectric of Three-Conductor Cable. TRANS. A. I. E. E., P. 221, Vol. XXXVII, 1918.

Fortescue, Chas. The Calibration of Current Transformers by Means of Mutual Inductances. TRANS. A. I. E. E., P. 1599, Vol. XXXIV, 1915.

Harned, Mark L. Operating Characteristics of Current Transformers. *Electrical World*, P. 869, Vol. LXVII, 1916.

Kennelly, A. E. and Velander, E. Potentiometer Measurements at Telephone Frequencies. *Amer. Phil. Soc. Proc.* 58, P. 97, 1919.

Knopp, Otto A. The Commercial Standardization of Instrument Transformers. *Electrical World*, P. 92, Vol. LXVII, 1916.

Knopp, Otto A. New Current Balance for Calibration Work. *Electrical World*, P. 993, Vol. LXXV, 1920.

Laws, Frank A. Application of the Potentiometer to Alternating Current Measurements. *Electrical Measurements* (Mc Graw Hill, 1917) Chap. V.

Makower, A. J. Measurement of Phase Difference, *Electrician*, 58, P. 695, 1907.

Newman, M. G. Measurement of Alternating Current of Low Value. TRANS. A. I. E. E., P. 1489, Vol. XXXI, 1912.

Northrup, E. F. A new Instrument for the Measurement of Alternating Currents. TRANS. A. I. E. E., P. 263, Vol. XXIV, 1905.

Northrup, E. F. Null Methods. Resistance Measured by Differential Instruments. *Method of Measuring Electrical Resistance.* (Mc Graw Hill, 1912) Chap. III.

Pesterini, Signor. Apparatus for Measuring Very Strong or or Very Weak Currents. *Electrician*, P. 154 Nov. 2, 1917.

Robinson, L. T. Electrical Measurements on Circuits Requiring Current and Potential Transformers. TRANS. A. I. E. E., P. 1905, Vol. XXVIII, 1909.

Rosa, E. B. The Compensated Two-Circuit Electrodynamometer. *Bull. Bureau Stds.*, P. 43, Vol. III, 1907.

Rosa, E. B. and Lloyd, M. G. The Determination of the Ratio of Transformation and of the Phase Relations in Transformers. *Bulletin Bureau Stds.*, P. 281, Vol. VI, 1909.

Sharp, C. H. and Crawford, W. W. Recent Developments in A. C. Measurements. TRANS. A. I. E. E., P. 1517, Vol. XXIX, 1910.

Sharp, C. H. and Farmer, F. M. Measurements of Maximum Values in High Voltage Testing. TRANS. A. I. E. E., P. 1617, Vol. XXXI, 1912.

Silsbee, F. B. Improved Method of Testing Current Transformers. *Electrical World*, P. 667, Vol. LXX, 1917.

Sumpner, W. E. Measurement of Small Differences of Phase. *Phil. Mag.*, P. 155, Vol. IX, 1905.

Thomas, Benj. F. Notes on Wiping-Contact Methods for Current and Potential Measurements. TRANS. A. I. E. E., P. 263, Vol. IX, 1892.

Weibel, Ernest. A Study of Electromagnet Moving-Coil Galvanometers. *Bulletin Bureau Stds.*, P. 23, Vol. XIV, 1918-19.

Wenner, Frank. Characteristics and Applications of Vibration Galvanometers. TRANS. A. I. E. E., P. 1243, Vol. XXXI, 1912.

Wescott, E. C. Differentially Wound Watthour Meter for Testing Current Transformers. *Electrical World*, P. 433, Vol. LXXV, 1920.

Whitehead, J. B. and Isshiki, T. Notes on the Synchronous Commutator. TRANS. A. I. E. E., P. 407, Vol. XXXIX, 1920.

Permeability

BY THOMAS SPOONER

Associate A. I. E. E.
Westinghouse Electric and Manufacturing Co.

Introduction

When we use the term magnetic permeability we ordinarily think of it as defined by the ratio of $B/H = (\mu)$, where B is expressed in gausses and H in gilberts per centimeter. It is the ratio of the flux in a magnetic circuit produced by a given magnetizing force to the flux which would exist if there were no magnetic material present. If we are considering permeability values for inductions less than that at which maximum μ occurs the true permeability

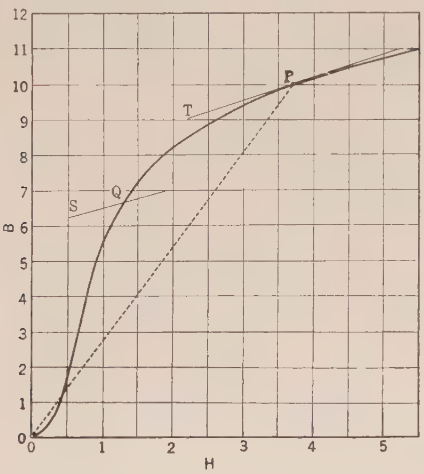


Fig. 1—Magnetization Curve Showing Different Kinds of Permeability

is given only when the material has been carefully demagnetized by applying gradually decreasing reversals of magnetizing force. Referring to the magnetization curve of Fig. 1 the permeability of the material at the induction P is given by the slope of the dotted straight line $P\,O$.

There are, however, other less well known types of permeability. For instance, we have the so-called differential permeability (μ_d) which may be defined as dB/dH for any point on the magnetization curve. It is the rate of change of flux with respect to magnetizing force. At the point P the differential permeability is the slope of the tangent drawn through this point as represented by $T\,P$. The differential permeability may be greater or less than the ordinary permeability depending upon the induction at which it is taken. Another type of permeability is the reversible permeability (μ_r) of Gans[1]. If at any point on a hysteresis loop we apply a very small reverse magnetizing force, the induction will be slightly changed. If now, we return to the original magnetizing force the induction will return to approximately the original value with the production of a minute hysteresis loop. The change of flux with respect to magnetizing force under these conditions is termed by Gans' reversible permeability. The slope of the line through O indicates the magnitude of this type of permeability. We shall have more to say about this later.

Incremental Permeability

The type of permeability which we wish to consider here will be termed incremental permeability (μ_Δ)[2] and will be defined as $\Delta B/\Delta H$ where the change of B may range from the small values required by Gans' reversible permeability up to large values. We shall attempt to give a means of calculating its value at least approximately for any magnetic conditions regardless of the previous magnetic history of the material and for any known types of ferro-magnetic substance. A better conception of the nature of this incremental permeability may be had from Fig. 2. For any minor displaced loops superimposed on a major loop, as for instance, $a\,b$, $c\,e$, or $d\,f$, the μ_Δ will be the ratio of the

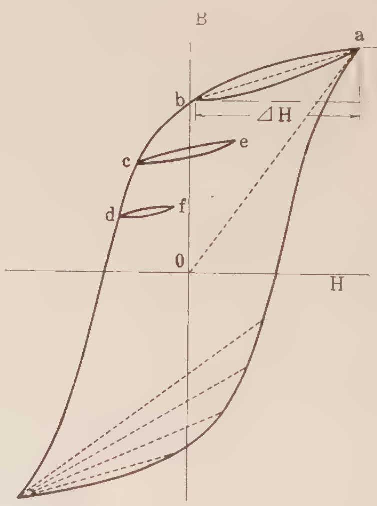


Fig. 2—Major and Minor Hysteresis Loops Showing Relation Between Ordinary and Incremental Permeability

difference of inductions for the two tips of the minor loops to the difference of the H values for these tips. For minor loops one of whose tips coincides with one tip of the major loop the incremental permeability is represented by the slopes of the dotted lines shown at the bottom of the major loop.

The mean slopes (μ_Δ) of these minor hysteresis loops is a function of two variables, *i. e.*

1. Die Reversible Permeabilitat auf der idealen Magnet esierungskurve, Richard Gans. *Annalen der Physik.* Vol. 61, No. 4, p; 379 (1920.

To be presented at the Midwinter Convention of the A. I. E. E., New York, N. Y. February 14-17, 1923.

2. Term suggested by Mr. Yensen.

1. For a given ΔB the greater the displacement of the minor loop from its normal position the less the incremental permeability (μ_Δ).

2. For a given displacement of a minor loop the greater the ΔB the greater the incremental permeability.

There is a number of cases where a method of estimating this type of permeability is desirable. For instance, suppose we wish to insert an iron core choke in a circuit carrying direct current. The effective reactance with respect to small alternating currents in the same circuit can not be calculated even approximately from a knowledge of the permeability of the core at the induction corresponding to the known d-c. magnetizing force as may be seen from an inspection of Fig. 2. Suppose the a-c. component of current produces a displaced hysteresis loop *a b*. Then the effective permeability of the core is not the slope of the line *o a*, but the line *b a*, which may be very much less. In radio circuits, where we have an iron-core choke coil in the plate circuit, for instance, we have exactly this condition.

Similarly in the case of a transformer with a d-c. component of current in one of the windings a knowledge of the incremental permeability is essential if we wish to estimate the value of the a-c. magnetizing current.

If it is desired to calculate the magnitude of the skin effect due to the high-frequency flux pulsations in the laminations which make up the teeth of an induction motor, for instance, a knowledge of the incremental premeability is essential since here we have the case of displaced minor hysteresis loops superimposed on a major loop.

Again take the case of the permanent magnet of a d-c. voltmeter or magneto. According to the usual practise this magnet is magnetized with a yoke across the air gap. The magnetizing force and yoke are then removed and due to the demagnetizing effect of the poles the magnet is partially demagnetized, for instance, to a point *d* (Fig. 2). Now when the regular pole pieces are applied this demagnetizing effect is decreased and we have an increased flux (point *f*). In order to estimate this increased flux and calculate the available magnetic energy for a given type of magnet steel a knowledge of the incremental permeability is essential.

In order to devise a method of estimating this type of permeability we have principally made use of the data in two previous published articles.[3,4] From the data of the first article we calculated the average permeability of various unsymmetrical loops and plotted these values against different variables. It was found that when plotting against pulsating amplitude a series of approximately straight lines was obtained as shown by Fig. 3. The values on the curve marked B_m indicate the maximum inductions of the minor loops. The short cross lines indicate the value at which the pulsating amplitude equals one-half the pulsating flux for the major loop. Now these curves can obviously be represented by a simple formula, thus,

$$\mu_\Delta = a + b \times \Delta B,$$

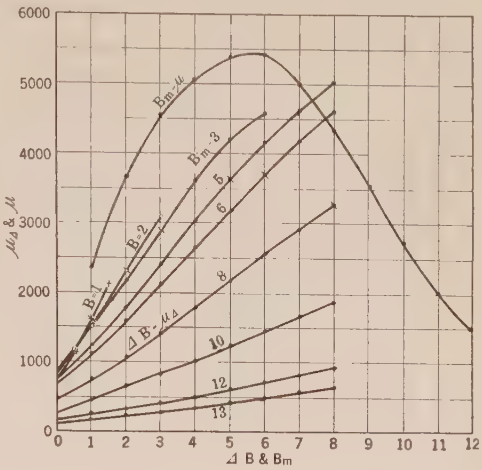


Fig. 3—Incremental Permeability as a Function of B_m and ΔB

where

a = intercept on the vertical axis,
b = slope of the line, and
ΔB = amplitude of pulsation for the minor loop.

From these data and other data largely taken from the results of the second above mentioned paper, the average curves for "a" and "b" are drawn as shown by Fig. 4.

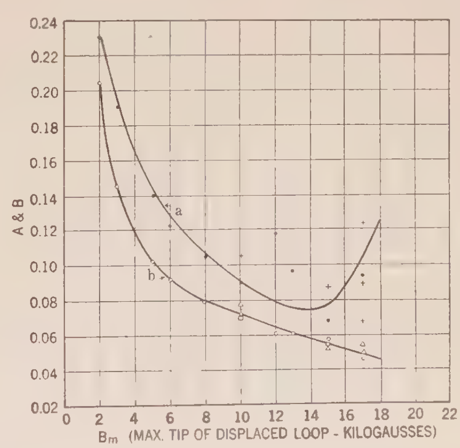


Fig. 4—Constants "a" and "b" for Incremental Permeability Equation $\mu_\Delta = \mu_m (a + bx \Delta B)$

A further examination of the various test results showed that the values of μ_Δ were also a function of the ordinary permeability (μ) of the material corresponding to the induction of the tip of the minor loops farthest from zero induction. The formula for incremental permeability is, therefore,

$$\mu_\Delta = \mu_{Bm} (a + b \times \Delta B), \text{ where}$$

---

3. The Effect of Displaced Magnetic Pulsations on the Hysteresis Loss of Sheet Steel, L. W. Chubb and T. Spooner. Proc. A. I. E. E., Vol. 34, 1915.

4. Tooth Frequency Losses in Rotating Machines, T. Spooner. Journal A. I. E. E., Vol. XL, Sept. 1921.

$\mu_\triangle$ = the incremental permeability or the average permeability for a displaced loop,

μ_{Bm} = the ordinary permeability corresponding to the induction of the tip of the loop farthest from zero induction,

a and b = constants as given by Fig. 4, and

ΔB = amplitude of flux pulsation of the minor loop expressed in kilogausses.

The value of "a" when B_m equals zero is one and approaches one again for high values of B_m: "b" approaches zero for high values of B_m.

In order to illustrate the difference between normal permeability and incremental permeability see Fig. 5. Here we have shown a normal permeability curve plotted against B_{max} and an incremental permeability curve also plotted against B_{max} where $\Delta B = 1$ kilogauss for the latter curve. As ΔB becomes smaller the difference between the two curves would increase and as ΔB becomes larger the difference would decrease.

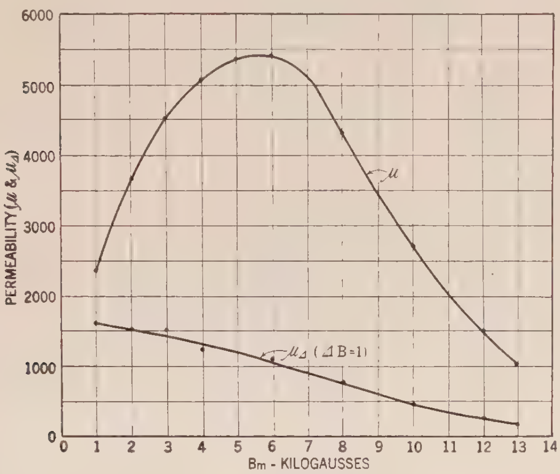


Fig. 5—Curves Showing Relation Between Ordinary and Incremental Permeability ($\triangle B21$) as a Function of Bm

Discussion of Results

It must be understood that this method of calculating $\mu_\triangle$ is merely an approximate empirical one and while it holds very well for most commercial ferromagnetic materials of very different properties ranging from permanent magnet steel to very high permeability vacuum iron, it is subject to considerable error for certain special types of material as will be pointed out later. If an attempt is made to use the formula for pulsating amplitudes (ΔB) much greater than one-half B_m the calculated results will in general be somewhat low. This can be seen for instance by an inspection of the $B = 3$ or $B = 5$ curves of Fig. 3. The average slope decreases at the higher pulsating amplitudes.

Now we need to give some consideration to the case of the minor loops which do not occur at the tips of the major loops. In the investigation of tooth pulsation losses in induction motors referred to above[4], a large number of minor loops were obtained located in various positions with a reference to the major loops of various magnitudes. So far as we could determine the average permeability for the minor loops is very largely independent of the magnitude of the major loops with which they are associated, but is chiefly determined by the amplitude and the displacement of the minor loops. A minor loop for a given amplitude and displacement will have a slightly higher $\mu_\triangle$ if it occurs on the downward branch of a major loop above zero induction than if it occurs below zero induction, but the calculated values will in general be between the two.

Mr. Searle[5] has published some data which may be used for checking our formulae. He applied a certain magnetizing force to his sample bringing it up to an induction, say of "a" Fig. 2. He then applied a certain demagnetizing force bringing his induction down to such a point as "o". He then reversed this demagnetizing force for two hundred times and determined his minor hysteresis loop. The $\mu_\triangle$ or average permeability for this loop equals his apparent permeability. The following tables I and II give results deduced from his data and also gives calculated results using our method. The only difference in the various values for a given material is that a different initial magnetizing force was used in each case, the first horizontal

TABLE I
IRON WIRE

B_m' Minor Loop	μ_m	ΔB	ΔH	$\mu_\triangle$ Test	$\mu_\triangle$ Cal	H_m
4.4	1760	1.03	3	340	474	2.5
3.65	1590	1.38	3	460	550	2.3
1.82	1040	1.93	3	645	694	1.75

μ_m is normal permeability corresponding to B_m'.
H_m is maximum H for major loop.
B_m' is the tip of the minor loop farthest from zero.

TABLE II
TAGGER PLATE

B_m' Minor Loop	μ_m	ΔB	ΔH	$\mu_\triangle$ Test	$\mu_\triangle$ Cal	H_m
6.8	4110	3.67	2	1840	1800	1.65
4.8	3870	4.71	2	2350	2500	1.24
*2.78	2780	5.56	2	2780	2960	1.00

*Normal loop.

We have obtained similar data on ring samples of commercial sheet with the results as shown by Tables III and IV.

TABLE III
0.014" 2¼ PER CENT SILICON STEEL

B'_m Minor Loop	μ_m	μ	ΔB	ΔH	$\mu_\triangle$ Test	$\mu_\triangle$ Cal.	Major Loop H_m	Major Loop B_m
4.77	3670	3260	6.07	2	3030	2930	30.0	14.8
5.33	3600	980	0.73	1	730	756	30.0	14.8
4.1	3630	3330	6.3	2	3150	2960	4.4	10.0
4.77	3670	1020	0.77	1	770	842	4.4	10.0

μ = normal permeability corresponding to $\dfrac{\Delta B}{2}$

5. Studies in Magnetic Testing, G. F. C. Searle. I. E. E. Vol. 34, page 55 (1904).

line corresponding to the highest magnetizing force. This means that the first horizontal line corresponds to the largest major loop.

There are some interesting points in connection with these loops.

a. The first minor loop has 10 to 20 per cent higher permeability than the 100th loop.

b. This change is nearly complete at the end of ten double reversals and is quite complete (within the limits of accuracy of test) at 50 double reversals.

TABLE IV
0.028″ BESSEMER

B_m' Minor Loop	μ_m	μ	ΔB	ΔH	μ_Δ		Major Loop	
					Test	Cal.	H_m	B_m
6.25	2030	400	0.50	2	250	357	6.15	10.0
7.65	1960	370	0.45	2	225	294	30.	15.45

c. After 100 double reversals the minor loop has shifted down towards the horizontal axis to a very slight amount only (perhaps 2 or 3 per cent on the average) as shown by measuring the change in induction when going to the lower tip of the major loop.

It will be seen from these data that the low values of permeability obtained from a magnetic test sample which has been insufficiently demagnetized is simply a case of displaced loops and if we know the displacement we may calculate the corresponding effective permeability (μ_Δ), which will be the test value under these conditions. The test μ_Δ should be compared with the normal permeability (μ) for the undisplaced loop of the same B amplitude. It will be seen that the μ_Δ values are always lower.

TABLE V
BALL'S DATA

B_m	μ_m	ΔB	ΔH	μ_Δ	
				Test	Cal.
12	2310	4	5.45	735	775
10	3510	4	3.35	1190	1330
8	4450	4	2.4	1670	1900
6	4610	4	1.9	2100	2290
4	4000	4	1.6	2500	2550
*2	2700	4	1.48	2700	2840
11.5	2880	3	4.18	718	786
9.5	4130	3	2.65	1130	1290
7.5	4690	3	2.05	1460	1670
5.5	4660	3	1.68	1780	1980
3.5	4110	3	1.37	2190	2320
*1.5	2310	3	1.30	2310	..
11	3140	2	3.3	607	698
9	4190	2	2.3	870	1040
7	5000	2	1.68	1200	1430
5	4420	2	1.41	1420	1550
3	3750	2	1.15	1740	1800
*1	1670	2	1.14	1750	..
10.5	3690	2	2.15	465	580
8.5	4720	1	1.52	658	850
6.5	5000	1	1.12	892	1050
4.5	4280	1	1.05	952	1130
2.5	3330	1	0.85	1180	1270
*0.5	1320	1	0.76	1320	..

*Symmetrical Loop.

As a further check on our formulae we took Ball's data[6] and determined the μ_Δ for his test results. We then compared them with the values obtained from our formula. Table V gives the results. One tip value of the minor loop coincides with the tip value of the major loop in all cases.

Now to come to the limiting case of Gans of very small pulsating amplitudes, namely, the case of reversible permeability. This should be given by the first part of our formula, thus

$$\mu_\Delta = \mu_{Bm}\ a,$$

since ΔB and therefore b are negligible. It will be found by comparing our results with those of Gans that the values do not check well. This is due to the fact that as shown by Gans' reversible premeability is a function of the initial permeability at low and moderate inductions which varies quite considerably for various materials. For pulsating amplitudes of any appreciable magnitude when "b" becomes an important factor the results will be much more accurate since "b" is not subject to much variation for different materials (see Fig. 4), where the circle and triangle points are "b" values and the dots and crosses are "a" values. If we were to take into account the variations of the initial permeability we would have to use a different curve for each material.

TABLE VI
GAN'S DATA

Material	$K_0 = \left(\frac{\mu_0 - 1}{4\pi}\right)$	B	$\mu\ B_m$	μ_Δ (μr)	
				Cal.	Gans
Hard Steel.......	41.8	12.9	99.2	7.55	15.0
" "	41.8	7.54	130.0	14.3	34.0
" "	41.8	2.51	68.0	13.9	43.0
Annealed Steel.....	71.0	15.7	131.0	11.0	8.0
" "	71.0	7.54	471.0	51.9	59.0
" "	71.0	2.51	209.0	42.7	70.0
Soft Iron.........	92.0	17.6	116.0	15.8	10.0
" "	92.0	7.54	1680.0	185.0	72.0
" "	92.0	2.51	838.0	176.0	89.0
Nickel...........	11.2	4.06	24.0	3.89	6.8
"	11.2	2.51	50.2	10.2	10.1

Mr. Gans has given test results for four samples as shown by one of the previously mentioned articles[1]. The following table VI gives his results as compared with our calculated results.

K_o and μ_o are respectively the initial susceptibility and initial permeability for the samples (equals the susceptibility and permeability as H approaches zero). If the reversible permeability is required accurately, it may be calculated by the following formulas due to Gans:

$$\frac{K_r}{K_o} = \frac{1}{X^2} - \frac{1}{\sin^2 X}$$

$$\frac{I}{I\ \alpha} = \cot X - \frac{1}{X}$$

$K_r = (\frac{\mu_r - 1}{4\pi})$ is the susceptibility for any given in-

6. The Unsymmetrical Hysteresis Loop, John D. Ball. Trans. A. I. E. E., page 2693 (1915).

tensity of magnetization $I_\alpha = \left(\frac{(B-H)}{4\pi}\right)$

K_r is the initial susceptibility corresponding to zero H. $I\alpha$ is the saturation value of the intensity of magnetization.

The difficulty in using these formulas is that ordinarily we do not know either the initial susceptibility or the saturation induction since both are rather difficult to obtain experimentally.

The data of table VII were obtained from tests of various experimental alloys having a wide range of properties, and serves to show the accuracy and limitations of our formula.

The data of sample A refers to a major loop having a maximum induction of 14 kilogausses. The minor loops therefore start at a considerable distance down on the demagnetization curve of the material. For all the other samples the maximum tip of the minor loop coincides with the maximum tip of the major loop and the permeability, therefore, corresponds to the slopes of the dotted lines of Fig. 2.

Sample B is a hard chromium magnet steel, and sample C is a much softer specimen of the same sample.

Samples D, E, F and G are nickel-iron alloys supplied by Mr. Yensen. Samples E and G have very low retentivity. Sample F has a low saturation value of the order of 5 kilogausses.

Sample H is a very pure iron having a very high retentivity value.

Samples I, J and K are approximately 4 per cent silicon-iron alloys having very high maximum permeability and low hysteresis.

These samples have been selected because of their very wide variations in magnetic properties. It is seen that with very few exceptions the checks between calculated and test values are quite good, certainly good enough for any ordinary commerical calculations. When the retentivity is exceptionally low or exceptionally high (see samples E and G for low B_r values and I for high) the checks are not so good, but for materials having anything like normal B_r values regardless of the permeability whether 20,000 or 20 the calculated results check the test results very well. No check results in addition to those already presented are given for commercial electrical sheet, but in all cases that we have examined the calculated results may be relied on to within 10 or 20 per cent even in the completed apparatus.

When an air gap is present in the magnetic circuit a little different procedure is necessary in order to calculate the effective permeability. First from the known characteristics of the material calculate μ_Δ, then $\Delta H = \frac{\Delta B}{\mu_\Delta}$. Now calculate or determine experimentally the gilberts per centimeter necessary to overcome the reluctance of the air gap, namely, the magnetizing force used up in the air gap to produce a change in the iron induction of ΔB. Let this be ΔH_g. If the air gap is very short this will be approximately ΔB times the length of the gap in centimeters. Then we have $\mu_\Delta \text{ (actual)} = \frac{\Delta B}{\Delta H + \Delta H_g}$.

The "a" and "b" curves of Fig. 4 have not been carried below B_m values of 2 kilogausses because the effect of displacement is very small for small displace-

TABLE VII
MISCELLANEOUS SAMPLES

Sample	Material	B_m	H_m	ΔB	ΔH	μB_m	μ_Δ Test	μ_Δ Cal.
A	Cr Magnet Steel Hard	8.8	—16.5	1.8	36.5	166.0	49.4	40.1
	" " " "	7.2	—7.7	2.2	41.3	147.0	53.3	44.2
B	" " " "	14.0	200.0	1.0	85.0	70.0	11.8	9.9
	" " " "	14.0	200.0	4.0	200.0	70.0	20.0	22.0
	" " " "	14.0	200.0	14.0	250.0	70.0	56.0	62.6
C	" " " Soft	14.9	200.0	1.0	95.0	74.6	10.5	10.4
	" " " "	14.9	200.0	5.55	200.0	74.6	27.7	29.7
	" " " "	14.9	200.0	14.9	214.9	74.6	69.4	69.5
D	50 Per Cent Nickel Steel	10.0	4.1	1.0	1.35	2440.0	740.0	412.0
	" " " " "	10.0	4.1	6.0	3.9	2440.0	1540.0	1279.0
E	34.5 " " " "	10.0	29.5	2.0	16.7	340.0	120.0	82.0
F	20 " " " "	4.0	21.0	1.0	14.5	190.0	69.0	54.0
	" " " " "	4.0	21.0	1.8	21.0	190.0	86.0	73.0
G	14.9 " " " "	10.0	27.7	2.0	14.0	361.0	143.0	85.0
H	Pure Iron	10.0	0.085	1.0	0.085	11750.0	1175.0	1980.0
	" "	10.0	0.085	5.0	0.119	11750.0	4200.0	5320.0
	" "	10.0	0.085	10.0	0.130	11750.0	7690.0	9500.0
I	Silicon Steel	10.0	0.435	1.0	0.0335	23000.0	2980.0	3880.0
	" "	10.0	0.435	5.0	0.0535	23000.0	9350.0	10400.0
	" "	10.0	0.435	10.0	0.0585	23000.0	17100.0	18600.0
J	" "	10.0	0.638	1.0	0.478	15700.0	2090.0	2660.0
	" "	10.0	0.638	5.0	0.748	15700.0	6690.0	7110.0
	" "	10.0	0.638	10.0	0.798	15700.0	12500.0	12670.0
K	" "	10.0	0.75	1.0	0.53	13300.0	1890.0	2250.0
	" "	10.0	0.75	5.0	0.82	13300.0	6100.0	5760.0
	" "	10.0	0.75	10.0	0.83	13300.0	11400.0	10740.0

ments and it is just as well or better under these conditions to use the ordinary permeability corresponding to ΔB. For values above B_m equals 18 kilogausses the hysteresis loop practically collapses and the values of μ_Δ can just as well be calculated from the ordinary magnetization curve and will be equal approximately to the differential permeability for the mean pulsating induction.

In using this method of calculating μ_Δ there are a few precautions to take, for instance, if we have the case of an iron core with a magnetizing winding carrying both alternating and direct currents, the maximum induction in the iron can not be obtained with certainty from the d-c. magnetization curve of the material and the value of the d-c. magnetizing component, but for moderate values of induction it will be higher and possibly very much higher due to two causes. In the first place the maximum magnetizing force is the arithmetical sum of the d-c. and maximum a-c. components of the magnetizing force and second the magnetic particles may be more readily oriented since they are shaken up by the a-c. magnetizing force. If the a-c. component of magnetization is sufficiently large the apparent d-c. magnetization curve will be approximately a straight line passing through the induction point corresponding to the maximum permeability and through the origin. Above the point of maximum permeability the a-c. has little effect on the d-c. magnetization curve.

Again if the a-c. frequency is high enough or the laminations thick enough we shall have skin effects which may make the effective permeability much less than the normal d-c. value[7] and will make μ_Δ less than that calculated by the above formula when a d-c. component of magnetizing force is present. This was evidently a large factor in the results obtained by A. W. Smith[8], where he found even for symmetrical conditions an effective a-c. permeability of about 1/5 the d-c. value at 500 cycles. As an illustration of the use of the μ_Δ values we had occasion recently to put an autotransformer in a d-c. circuit as a choke for a small high-frequency component which was also present in the circuit. The effect of this choke could of course be determined from a knowledge of the inductance which might be calculated by the following well known formula

$$L = \frac{4\,\pi\,N^2}{R},$$

where

$$R = \frac{l}{\mu\,A}$$

Now taking the permeability corresponding to the maximum induction due to the d-c. component as determined from a magnetization curve of the core material we would obtain a certain value for L. If, however, instead of using μ_{max} as determined above, we use the correct value μ_Δ, the value of the inductance for the particular conditions considered is about 1/20 the value obtained by using μ_{max}.

Conclusions

We have given an approximate method of calculating the ratio $\frac{\Delta B}{\Delta H} = (\mu_\Delta)$ usually with an error of not greater than 10 per cent or 20 per cent for any class of ferro-magnetic materials regardless of the magnitude of ΔB and ΔH and of the previous magnetic history. The results will be more accurate if the amplitude of B is considerable. For very small values of ΔB the result may be rather unreliable. In order to calculate μ_Δ for any value of ΔB and any value of magnetic induction B_m we need simply to know the ordinary permeability (μ) of the material corresponding to B_m and the constants "*a*" and "*b*" as given by Fig. 4. It is rather surprising that this method checks as well as it does due to the fact that the curves of Fig. 4 are based on rather meager data involving only a few samples. We might have increased the accuracy by using a different "*a*" curve for different classes of material but this would have complicated the method and is not necessary except when considerable accuracy is required or when the ΔB values are very small. It is hoped that this simple method may find application for the solution of various electrical problems as suggested in the early part of this paper.

7. Losses in Sheet Steel at Radio Frequencies, Marius Latour Institute Radio Engineers, Feb. 1919, page 61.

8. Effect of a Superimposed Constant Field upon the Alternating Current of Permeability and Energy Loss in Iron, A. W. Smith, *Physical Review*, March 1921, page 416.

SULPHATION OF BATTERY PLATES

An investigation has been undertaken by the Bureau of Standards to establish, if possible, a speedy and accurate method for the measurement of the effect of impurities in storage battery electrolytes. Methods which have previously been used require considerable time, and accurate and consistent results are difficult to obtain with them. The new method which has been devised is based upon successive weighings of the positive or negative plates while immersed in the solutions to be tested, which are maintained at a constant temperature. The battery plates were immersed in the various electrolytes contained within a thermostat bath and so arranged that any plate could be brought in the arm of a sensitive balance for weighing. Weighings of the plates were made daily, and the results were computed as the increase in weight of the plate per hour. The results showed considerable differences in the rates of sulphation of plates made by various manufacturers, and marked differences in the rate of sulphation produced by different concentrations of the acid solution were demonstrated. Temperature also plays an important part in determining the rate of sulphation.

Qualitative Analysis of Transmission Lines

BY H. GOODWIN, Jr.
Member, A. I. E. E.
Engineering Staff of Sanderson & Porter, New York, N. Y.

Review of Subject.—*The process proposed in this paper is called "Qualitative Analysis of Transmission Lines" because of its similarity to chemical qualitative analysis.*

Based upon a previous presentation by Mr. Percy H. Thomas the "critical load" for transmission lines is introduced with a simple formula for determining it and various rules are given for the variation of power factor voltage, etc., of a line by relating the actual load to the critical load.

The most important parts of Mr. Thomas's presentation are abstracted and presented showing the fundamental physical and mathematical basis for this method of analysis.

The detail development of the formula for the critical load is then given and the effect of the various line constants upon it are briefly discussed.

Working from the critical load a vector interpretation of the action of a long high-voltage transmission line is given. From this vector interpretation it is possible to predict certain essential operating characteristics of transmission lines.

Based on the previous generalities practical examples of transmission lines operating at critical load are then given showing how it is possible by the qualitative analysis to predict desired conditions of operation. Two of these examples show the operation of a 3100 mile copper transmission line of 220 kv. nominal potential. Another shows a 3875-mile aluminum transmission line.

In the conclusion an appeal is made for further work along these lines and it is pointed out particularly that this is not an approximate method but an exact method for "Qualitative Analysis of Transmission Lines."

Introduction

THIS paper is entitled "Qualitative Analysis of Transmission Lines" because of the similarity of the process set forth to *qualitative* analysis in chemistry. Transmission line calculations according to the well-known formulas can be considered as in the class of *quantitative* chemical analysis; results are obtained not only giving the character of the quantities but also their amounts.

The value of *qualitative* analysis of transmission lines lies first in the results obtainable by the simple rules set forth. But it has a second and greater value to one trying to arrive at a conception of what is really happening in a transmission line; it gives a basis for a mental picture and a true conception of the evolutions in the line and the effects upon them of changes in any of the constants.

Critical Load

The qualitative analysis proposed is based upon the fact that for each transmission line there is a *critical load* which at unity power factor behaves practically like direct current on the line.

Analyses are made by relating the load conditions for a given line to this critical load.

The critical load was first discovered and presented to the Institute by Mr. Percy H. Thomas in 1909[1]. Unfortunately little practical use has been made of Mr. Thomas's discovery. The physical concept behind the critical load formula can not be better given than in Mr. Thomas's own words which will be quoted later.

Starting from Mr. Thomas's conclusions, the formula for the critical load of any transmission line has been derived and is as follows:

$$\text{kv-a.} = \frac{10^3\,(\text{kv.})^2}{\sqrt{L/C}} \tag{1}$$

For commercial lines this can be expressed with accuracy within 5 per cent:

$$\left.\begin{aligned} \text{kv-a.} &= \frac{(\text{kv.})^2}{0.4} \\ \text{or:}\quad \text{kv-a.} &= 2.5\,(\text{kv.})^2 \end{aligned}\right\} \tag{2}$$

If the "*Y*" voltage is used the result is kv-a. per phase. If the delta voltage is used the result is total kv-a.

For a few voltages within the ordinary commercial range the critical loads are as follows:

Volts	Critical Kv-a.
200,000	100,000
141,000	50,000
100,000	25,000
60,000	9,000
20,000	1,000
10,000	250

Some of the properties of the critical load which are useful in analysis of transmission lines of present commercial lengths are as follows:

(1) The critical load when placed on a transmission line at unity power factor will be transmitted at unity power factor. The current will be constant throughout the line. The voltage drop will be the same as for direct current ($I\,R$). The power loss will be equal to the direct-current power loss ($I^2\,R$).

(2) If the kv-a. load is greater than the critical load, the power factor at the sending end of the line will be always more lagging than the power factor at the receiving end of the line.

(3) If the kv-a. load is less than the critical load, the power factor at the sending end of the line will always be more leading than the power factor at the receiving end of the line.

(4) If the load is the critical kv-a. but at a leading power factor, the power factor at the sending end of the line will be still leading but nearer unity.

(5) If the load is the critical kv-a. but at a lagging power factor, the power factor at the sending end will still be lagging but nearer unity.

1. "Output and regulation in Long Distance Lines"; Percy H. Thomas, TRANSACTIONS, A. I. E. E. 1909.

To be presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 14-17, 1923.

If the line is longer than any line now in commercial service either leading or lagging critical loads should finally reach the stable condition at a very slight leading power factor, usually better than 0.995.

For a line of unusually large diameter at a small spacing or unusually small diameter at a large spacing the value of $\sqrt{L/C}$ should be taken from Fig. 1 and used in formula (1). The accuracy of formula (2) is however within 5 per cent plus or minus for present commercial transmission systems.

The values of the critical kv-a. with various voltages may easily be read from the slide rule by setting it as shown in Fig. 2. Set "4" on scale B opposite "1" on scale A. The rider is set to the voltage on scale C and the critical load read on Scale A. The decimal point can best be determined by remembering that the critical load for 100 kv. is 25,000 kv-a.

Quotations From "Output and Regulation in Long Distance Lines," by Percy H. Thomas

As stated above the physical conception and fundamental mathematics of the critical load of a transmission line were presented by Mr. Thomas in 1909. Nothing better can be said than what he wrote at that time. The more important parts of his presentation are as follows:

"*Electrical Action in the Line.* The critical electrical feature of a transmission system is the action of the line itself. In the passing of energy over a line there is, first, the loss of energy in practical overhead work represented only by the resistance losses. But with power passing over a line at high voltage, a certain amount of leading energy flows to charge the line capacity. This energy in its travel causes a tendency for the potential to rise along the line in the direction of the flow of the leading energy. Similarly there flows to the line a quantity of lagging energy, by virtue of the inductance of the line and the flow of current therein. This lagging energy tends to cause a drop of potential in the line in the direction of its flow. The resultant effect is the difference of the leading and lagging energy-flow, superimposed, of course, upon the true power transmitted and the resistance-drop. * * * * *

"When the lagging energy predominates over the leading energy, the tendency is for a drop in potential along the line in the direction of the lagging flow—the well known inductive drop, which is combined with the ohmic drop.

"When the leading energy predominates there is a tendency for a rise of potential in the direction of the leading energy-flow, which must be combined with the ohmic drop as before. The rise of potential effect of the leading energy will be opposed to the ohmic drop when the transmission of power and the flow of leading energy are in the same direction. * * * * *

"Now consider the case when the leading and the lagging energies are equal and when they are opposite in phase; that is, when the load power factor = 1. In this case there will evidently be no appearance in the line of demand on the generator for either lagging or leading energy, and no tendency either for a rise or a drop of voltage therefrom, and the ohmic drop is the only loss of voltage. This condition will be actually realized in practise if the leading and lagging energies of the line are equal and with a load of unity power factor. If, however, the load current has a lag or a lead, the leading and lagging energies, while they may be equal, will not be opposite in phase and will not neutralize each other. The rather remarkable conclusion follows —that in this case of complete neutralization the loss of voltage is only the ohmic drop and is independent of frequency and is of the same value as with the direct current. Thus if this condition can be realized, and there enters no secondary effect, there will be no further economy in direct-current transmission as far as energy loss or voltage line drop is concerned, the same effective line voltage being used. But the diffculty is that this condition of equality of the leading and the lagging energy in the line is usually not met with in practical transmission of relatively short length and often cannot be economically obtained.

"The unfortunate condition exists that the leading energy, being the condenser energy, is practically constant, whatever the load on the line, since it depends only on the voltage of the line. On the other hand, the lagging energy depends only on the actual amount of power or current being transmitted, since it varies as the square of the line current. Thus with half load or no load, a line that was balanced for full load would have a large excess leading energy flow.

* * * * * *

"It should be carefully borne in mind that the leading and lagging energy and energy-loss so far discussed are wholly confined to the line and have no necessary relation to the leading or lagging current in the load.

"The factors by which the relative values of the leading and the lagging energy of the line are controlled are: the line voltage, the actual load or current, and the ratio of the line inductance and capacity per unit length. The energy taken by the capacity of the line varies as the square of the line voltage, so that this factor is of extreme importance. The lagging energy of the load varies as the square of the current, as has already been mentioned. Neutralization of the leading and lagging line energies can be obtianed only when the power factor of the load current is unity, for only then the leading and lagging energies are opposite in phase.

"The current of the line, of course, decreases directly with the increase of line voltage chosen, if the power transmitted be kept constant.

"The energy flowing to the capacity of the line per unit length is porportional to pCV^2, where pC is the capacity susceptance and V the voltage. The lagging energy will be proportional to pLI^2, where pL is the inductive ohms and I the current. If these are equal

then $V/I = \sqrt{L/C}$, which is the condition of balanced out-of-phase energy. It is clear that this can be reached for any line and voltage by properly choosing the current, and for any current by properly choosing the voltage. It is also clear that the condition is independent of frequency.

"Equation (**34**) of the companion paper gives the line voltage equation when $R = O$. Here if the current or voltage is chosen to fulfill the above condition.... the voltage of the line is constant as it should be. The resistance is chosen as zero, as otherwise the change of voltage along the line will destroy the exact balance of the leading and the lagging energy.

"Thus as the net result, the ratio of the leading to the lagging energy varies as the fourth power of the voltage when the power transmitted remains the same. The capacity of the line can be increased by adding condensers in parallel across the line at regular and sufficiently frequent intervals; the inductance can similarly be increased by the addition of choke coils in the same manner. But these expedients have never found much favor. As the power and voltage are often fixed by the other considerations, some other method of altering this ratio than change of power or voltage would be desirable. * * * * * * * *

"It should be said that in this matter of adjustment of the leading and lagging line energies, a change of frequency is of no avail, since both elements, capacity and inductance, are affected in the same manner. Furthermore, while a certain voltage may be most favorable in some particular case for balancing the line effects and reducing the line-drop to the ohmic equivalent, it does not necessarily follow that this voltage will give the best transmission condition, for the advantage of a higher voltage may easily more than offset the favorable adjustment of the leading and lagging energy of the line. Furthermore, the most favorable line conditions will not always be the most favorable for other parts of the system and any complete design will be a compromise, as usual. * * * *

"In the main the electrical action of the line has now been briefly outlined. The most notable features are:

"1. That by properly balancing the leading or capacity energy and the lagging or inductive energy in the *line itself*, the full-load transmission will be as though the line had only ohmic resistance.

"2. That a reasonable constancy of voltage conditions on the line *for all loads* may be obtained by supplying the leading energy in the condition when the load is off or light, partly or wholly from the receiving end. * * * * * * * *

Summary

"The more important definite conclusions arrived at may be summarized as follows:

"1. To obtain the most economical transmission of power over a long-distance line, it is necessary to have balanced the leading and lagging energies of the line itself, and at the same time to have unity power factor in which case the transmission is similar to direct-current both as to voltage drop and energy loss.

"2. The power factor at the load end may be made unity or otherwise controlled by synchronous machines, generators or motors, located at the receiving end of the line.

"3. To obtain satisfactory regulation for high-power long-distance transmission, the leading current taken by the line at light loads should be fed mainly from the receiving end. By this means the voltage rise from the receiving end; that is, the drop from the power house to the receiving end, can be kept nearly constant for all loads. Adjustment of the line-drop can be accomplished at any load by varying the amounts of the leading energy or charging current supplied to the respective ends of the line.

"4. The voltage regulation and line losses may be controlled for any commercial frequency and for any percentage load condition—as far as its electrical action is concerned—using a conductor of sufficient section, by making the leading and lagging line-energies equal at full load, and by feeding suitable proportions of the charging current at other loads from the respective ends of the line, the greater portion being from the receiving end.

"5. The adjustment of the leading and lagging energies taken by the line itself may be accomplished by the choice of voltage and load, or by adjusting the ratio of the capacity and inductance of the line. . . .

"6. Calculations of these long high-voltage, high-power lines may be made approximately only by formulas founded on the assumption of localized capacity. The error in the voltage may be several per cent. The approximate formulas are especially unreliable when the leading and lagging energy in the line are equal.

* * * *

"9. While it is possible by a cut-and-try method for any given case to arrive at the best conditions of capacity, resistance, inductance, and the power-factor at the load end of the line, yet, the best results will be obtained most directly by planning the line in accordance with the principles here explained.

"While comparatively few high-tension power-transmitting systems now installed are of sufficient magnitude to require as careful a treatment as that outlined here, the development of this art cannot proceed much further without some such method. It is the hope of the writer that here, either directly or, perhaps more likely, by suggestion, he has somewhat forwarded this development."

Evolution of Formula for Critical Load

Mr. Thomas, as quoted above, gives the fundamental relation for the critical load: $V/I = \sqrt{L/C}$. This

can be converted into the more convenient form given in the earlier part of this paper as follows:

Let kv-a. = total kv-a.

$(\text{kv-a.})_p$ = kv-a. per phase

E = delta voltage in kv.

$e = \dfrac{V}{1000} = Y$ voltage in kv.

I = current per phase

Then kv-a. $= 3\,(\text{kv-a.})_p$

$e\,I = (\text{kv-a.})_p$

$I = \dfrac{(\text{kv-a.})_p}{e}$

Substituting:

$$V/I = \frac{1000\,e}{I} = \frac{1000\,e}{\dfrac{(\text{kv-a.})_p}{e}} = \frac{1000\,e^2}{(\text{kv-a.})_p} = \sqrt{L/C}$$

$$\therefore\ (\text{kv-a.})_p = \frac{1000\,e^2}{\sqrt{L/C}} \qquad (3)$$

$$\text{and kv-a.} = \frac{1000\,E^2}{\sqrt{L/C}} \qquad (4)$$

These last two equations, (3) and (4), are of exactly he same form. The difference in notation shows that

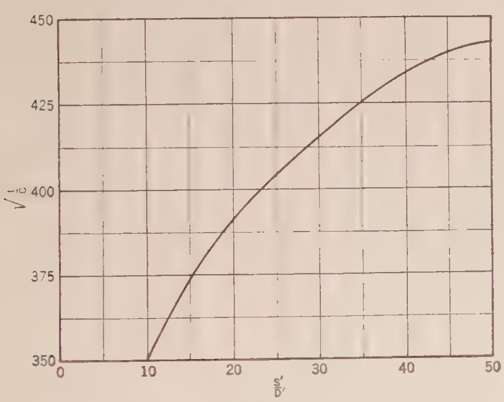


Fig. 1—Conductors in One Plane

S' = Distance between conductors in feet; D' = Conductor diameter in inches. For conductors in triangular arrangement: divide $\dfrac{S'}{D'}$ by 1.26 and use result. $\sqrt{\dfrac{L}{C}}$ for all sizes and spacings of aerial high-tension lines.

if the Y voltage is used the result is the critical kv-a. per phase, while if the delta voltage is used the result is the total kv-a.

By applying practical values of conductor size and spacing to Fig. 1 it is found that $\sqrt{L/C} = 400$ is a fair average value. Substituting this value in equation (4) gives:

$$\text{kv-a.} = \frac{1000\,E^2}{400}$$

$$\text{kv-a.} = \frac{E^2}{0.4} \qquad (5)$$

in which E is expressed in kilovolts.

Discussion of Critical Load Formula

Equation (4) for the critical load may be rewritten:

$$\text{kv-a.} = 1000\,E^2\,\sqrt{C/L} \qquad (6)$$

In this form it shows plainly that an increase in the capacitance of the transmission line will increase the critical load; a decrease in capacitance will decrease the critical load. In contrast to this, an increase in the reactance of a line will decrease the critical load and a

Fig. 2

decrease in the reactance will increase the critical load. Since the capacitance and reactance of transmission lines fundamentally bear a reciprocal relation it is seen that any change in size or arrangement of conductors will affect the reactance and inductance inversely. This will change the value of the quantity under the root sign by the square of the factor of change. But since this is under the root sign it will only affect the kv-a. directly as the change in either one of the quantities. For instance if it were possible to increase the capacitance of a circuit 50 per cent and therefore decrease the inductance a similar amount the critical load would only be increased 50 per cent.

For very high-voltage lines the full loads will correspond quite closely to the critical loads. However light loads will depart very far from the critical loads and those experienced with such lines know that light load conditions often present greater problems than full load. Looking at equation (6) to determine what is necessary for light loads, it is seen that the critical load may be reduced by decreasing the capacitance of the line or by increasing the inductance. To decrease the capacitance of the line is a difficult thing, but remembering the derivation of the equation it is easy to see that the same result may be produced by reducing or neutralizing the charging current. This can be done by connecting reactance coils across the circuit at various points or by the use of synchronous phase-modifiers operated under-excited so as to draw a lagging current from the line. This second has the advantage that under full-load conditions the phase-modifiers could be over-excited to draw a leading current and so increase the critical load. These devices need not be uniformly distributed but can be lumped at different points as determined for each line. As a matter of fact

any line so long as to require modifying devices at other than the receiving end would probably have several distributing substations at which could be located the necessary modifying devices for proper operation at light-load, and increasing the critical load for full-load conditions. The decrease of the critical load for light load operation by increasing the inductance presents practical difficulties so that it will probably not be used for power transmission. This is the "loading coil" method used on telephone circuits where it is highly practical and the methods of decreasing the equivalent capacitance are impractical.

Vector Interpretation of Critical Load Transmission

The best conception of what is happening in a transmission line carrying its critical load at unity power

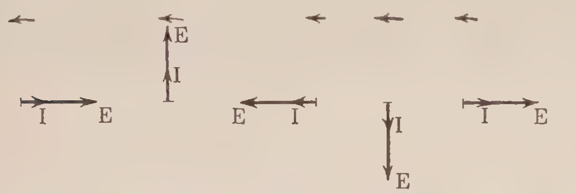


Fig. 3

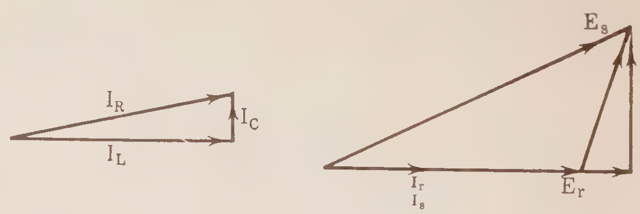
factor can be obtained by following Mr. Thomas's suggestion of assuming $R = O$. Mr. Thomas points out that under these conditions the effective values of current and voltage will be constant throughout the length of the line. In addition to this it should be noted that the vector position will change throughout the line. Starting from the receiving end with the current and voltage in phase and traveling toward the sending end the vectors will advance in a counter-clockwise direction (Fig. 3). At the end of a quarter wave-length both current and voltage vectors will be 90 degrees ahead of the vectors at the receiving end. At one-half wave-length the vectors will have advanced 180 degrees and will be in exact opposition to those at the receiving end. Continuing, at the end of one wave-length the vectors will be in phase with those at the receiving end but one revolution in advance. This can be continued indefinitely. Since electricity travels with the speed of light the wave-length for 60 cycles is 3100 miles and a quarter wave-length is 775 miles. Since the voltage and current are in phase at each point, full power is transmitted throughout. Resistance is then the only impediment to long distance transmission of alternating current electrical energy.

It is therefore necessary to investigate the effect of resistance on the transmission of the critical load. Mr. Thomas has pointed out that the voltage drop with the critical load at unity power factor will be $I R$. That is, the increase in voltage from the receiving end toward the sending end is directly proportional to the resistance involved. The critical load being proportional to the *square* of the voltage, it will increase at a rate dependent on the square of the resistance (R^2). The actual load is increasing by the line losses which are $I^2 R$ involving only the first power of R. This means the actual load is not keeping pace with the critical load and there must therefore be a change in phase relation of the current and voltage.

Going back to Mr. Thomas's fundamental conception, this disproportionate rise in voltage causes a flow of leading energy too great to be balanced by the lagging energy of the load current. This then must exhibit itself by a leading component of the current.

Fig. 4 shows the condition. I_L is the load current. I_c is the capacity current due to the increase of voltage above that corresponding to the actual load. I_R is the resultant current causing the power loss and voltage drop in the line. This resultant current enters as the square and since it is larger than I_L in some measure offsets the R^2 effecting increase in voltage, but the effect is very slight.

The leading current I_R has another effect and that is to decrease the voltage drop according to the familiar effect of a leading current flowing through inductance. These two actions will continue until the losses are at too rapid a rate for the slowly increasing potential. The action will then reverse and the current swing back in phase until the voltage is again sufficient to maintain the load and losses. The power factor would then again be near unity and the oscillation to leading would recur. This swinging of phase angle would continue until it finally settled at some value of advance which is very small, amounting only to from 2 to 6 degrees (power factor of 0.9994 to 0.9945) for commercial lines.



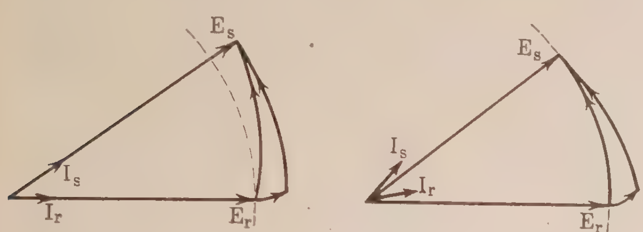
Figs. 4 and 5

It should be borne in mind that the relative conditions just described refer to the relation at different points along the line and not to varying conditions at one point. With the load constant the conditions at any point will be constant. But the phase relations will oscillate as different points along the line are considered.

The ideas presented in the previous paragraphs and some other conceptions can probably better be grasped by comparison with the familiar vector diagram of a current flowing through a lumped resistance and reactance without appreciable capacitance. In Fig. 5 E_r and I_r indicate the voltage and current at the

receiving end. E_s and I_s indicate the voltage and current at the sending end. It is to be noted that I_r and I_s are equal and in phase. E_r and E_s are connected by the impedance triangle of the reactance. The power factor is unity at the receiving end and lagging at the sending end.

Fig. 6 shows a similar diagram for a transmission line having distributed inductance and capacity with the critical load at unity power factor. The effect of the distributed inductance and capacity is to curve the sides of the impedance triangle and reduce the difference between E_r and E_s to an amount equal to



Figs. 6 and 7

$I R$. From the discussion in the first part of this section it is evident that I_s would lead E_s by an angle too small to be shown on the diagram.

Proceeding from Fig. 6 it is interesting to consider the conditions which might produce zero voltage drop in the line. It would appear that if I_r were advanced by a small angle equal to the small angle of the impedance triangle of the line that this might be accomplished. Advancing I_r would swing the impedance triangle about its lower corner so that E_s would be thrown in to the circle which has a radius of E_r. Fig. 7 shows the resultant conditions. The result of calculations given later show this to be true for two transmission lines of present commercial length.

Practical Examples of Transmission Lines Operating at Critical Load

Many of the generalities discussed in the preceding sections of this paper can be much better appreciated by a few practical calculations. The results of some of these will therefore here be given.

All of these calculations have been made by the use of the rigid hyperbolic formula and are of a high order of accuracy. A true sine wave has been assumed. The conductors have been considered as placed in one plane with sufficient transpositions to make them symmetrical.

Critical Load for Practical Lines:—In order to show the relation of the critical load to various lines now in service Table I has been prepared for a few lines of

TABLE I

$\sqrt{l/c}$ AND "CRITICAL KV-A." FOR VARIOUS HIGH-TENSION LINES

Company	Nominal kv.	$\sqrt{L/C}$	Receiver Volts kv.	Critical kv-a.
Southern California Edison	220	387	200	103,000
Pacific Gas and Electric	220	384	200	104,000
Great Western	165	391	150	57,500
Au Sable	140	420	125	37,000
Utah Power & Light	130	396	118	35,000
Tennessee Power	120	404	110	30,000
Connecticut Riv.	120	402	110	30,000
Pacific Gas & Electric	110	388	100	26,000
Au Sable	110	400	100	25,000
Hydro-Electric Commission Ontario	110	375	100	27,000
Georgia Railway & Power	110	381	100	26,000

110,000 volts and above. This table shows the critical load to be quite within the range of operation of most of these lines and its use would help in analyzing and understanding their behaviors.

Short Copper Transmission Line at Critical Load. Table II gives first the general specifications for a copper transmission line with very large conductors

TABLE II

OPERATING CHARACTERISTICS OF COPPER TRANSMISSION LINE AT "CRITICAL" LOAD

General Data

Length: 193.75 miles (¼ of ¼ wave-length)
Nominal Line Voltage .... 220,000 Volts
Frequency .... 60 Cycles
Conductor, copper, stranded .... 1,000,000 Cir. Mils.
" diameter .... 1.152 Inches
Spacing—flat .... 20 Feet

Resistance per mile at 20 deg. cent., 98 per cent Conductivity .... 0.0558 Ohms
Reactance per mile .... 0.791 Ohms
Susceptance " " .... 5.38 Micro-mhos.
$\sqrt{L/C} = 383.3$

There will be no corona at nominal voltage. In the calculations it has been assumed that there is no leakage loss.

Item	Predicted Flat Voltage		Power Factor 0.707 Lagging		Power Factor 0.707 Leading	
	Receiving End	Sending End	Receiving End	Sending End	Receiving End	Sending End
Volts (delta)	200,000	200,000	200,000	248,800	200,000	145,500
" (Y)	115,500	115,500	115,500	143,700	115,500	84,000
Load kv-a. (total)	104,400	107,100	104,400	91,000	104,400	93,210
" kw. "	104,200	106,900	73,800	75,750	73,800	77,400
" kv-a. (per phase)	34,800	35,700	34,800	30,330	34,800	31,070
" kw. " "	34,733	35,633	24,600	25,250	24,600	25,800
Current (Amperes)	301.2	309.0	301.2	211.0	301.2	370.2
Power Factor*	0.9975 *d*	0.9982 *d*	0.707 *g*	0.833 *g*	0.707 *d*	0.83 *d*
Angle (degrees)*	4.04 *d*	3.42 *d*	45.00 *g*	33.63 *g*	45.00 *d*	33.94 *d*
Critical Load (kv-a.)	104,400	104,400	104,400	161,700	104,400	55,300
Line Loss (kw.) (total)	2,700		1,950		3,600	
" " (kw.) (per phase)	900		650		1,200	
Line Drop (volts) (delta)	0		48,800		− 54,500†	
" " " (Y)	0		28,200		− 31,500†	
Per Cent Line Loss	2.59		2.64		4.9	
" " " Drop	0		24.4		− 27.3†	

*d = leading; g = lagging. †rise

and almost 200 miles in length. The results of the calculations for various conditions are then given. The voltage, current, load, etc. are shown at the receiving and sending ends of the line and the losses, etc. in the line. The first condition given is that for "flat" voltage predicted as described in connection with Figs. 6 and 7. This shows the accuracy with which flat voltage can be predicted for shorter lengths of line. It is to be noted that the critical load is constant throughout on account of the constant voltage. Due to the line losses the load kv-a. and kw. are both increased at the sending end above the receiving end. It is then to be expected that the current would tend to loose some of its original angle of lead on the voltage. This is shown by the decrease in angle from 4.04 degrees to 3.43 degrees.

It is interesting to note the very high power factor throughout the line which shows the necessity of dealing with the angle rather than with the power factor in calculating at critical load.

In order to demonstrate practically some of the rules given at the beginning of the paper there are also shown in Table II calculations for lagging and leading power factors. These show very plainly the tendency of the critical load when at lagging or leading power factor to increase toward unity power factor. The voltage, current and other conditions are well demonstrated in the table and can best be understood by a direct study of the table.

Short Aluminum Transmission Line at Critical Load: As was shown in the general section of this paper resistance really is the controlling factor with critical load transmission. In order to show the effect of resistance Table III has been prepared in every way similar to Table II except that a comparatively small aluminum conductor has been used instead of the large copper conductor.

Calculation was made for predicted flat voltage as before and this is practically checked by the result. The line power loss is 9.3 per cent. The large angles involved with the increased resistance are in great contrast to those involved with the copper line.

The results for lagging and leading power factor also show the effect of the increased resistance on many of the factors.

Characteristics of Very Long Transmission Line: In the general section of this paper it was shown in connection with Fig. 3 how the critical load could be carried to an infinite distance on a transmission line with no resistance. In connection with Fig. 4 the effect of resistance was discussed.

TABLE III
OPERATING CHARACTERISTICS OF ALUMINUM TRANSMISSION LINE AT "CRITICAL" LOAD

General Data

Length: 193.75 miles (¼ of ¼ wave-length)		Resistance per mile at 75 deg. Fah., (62 per cent Conductivity)	0.179 Ohms
Nominal Line Voltage	220,000 Volts	Reactance " "	0.833 Ohms
Frequency	60 Cycles	Susceptance " "	5.09 Micro-mhos.
Conductor, aluminum, stranded	500,000 Cir. Mils.	$\sqrt{L/C} = 405$	
" Diameter	0.81 Inches		
Spacing—Flat	20 Feet		

There will be no corona at nominal voltage. In the calculations it has been assumed that there is no leakage loss.

Item	Predicted Flat Voltage		Load Power Factor 0.707 Lagging		Load Power Factor 0.707 Leading	
	Receiving End	Sending End	Receiving End	Sending End	Receiving End	Sending End
Volts (delta)	200,000	201,500	200,000	255,000	200,000	157,000
" (Y)	115,500	116,300	115,500	147,300	115,500	90,700
Load kv-a. (total)	98,800	107,100	98,800	88,800	98,800	95,490
" kw. "	96,600	105,600	69,840	75,900	69,840	80,700
" kv-a. (per phase)	32,933	35,700	32,933	29,600	32,933	31,830
" kw. " "	32,200	35,200	23,280	25,300	23,280	26,900
Current (Amperes)	285.2	307.0	285.2	201.0	285.2	351.0
Power Factor*	0.9777 *d*	0.9862 *d*	0.707 *g*	0.855 *g*	0.707 *d*	0.845 *d*
Angle (degrees)*	12.13 *d*	9.58 *d*	45.00 *g*	31.25 *g*	45.00 *d*	32.35 *d*
Critical Load (kv-a.)	98,800	100,200	98,800	160,600	98,800	60,900
Line Loss (kw.) (total)	9,000		6,060		10,860	
" " (kw.) (per phase)	3,000		2,020		3,620	
Line Drop (volts) (delta)	1,500		55,000		− 43,000†	
" " " (Y)	800		31,800		− 24,800†	
Per Cent Line Loss	9.3		8.7		15.5	
" " " Drop	0.7		27.5		− 21.5†	

*d = leading; g = lagging. †rise

In order to show these points by a practical example, a transmission line 3100 miles long equal to one wave length at 60 cycles has been calculated and the results are shown in Table IV. The conditions at the receiving end have been chosen to give constant power factor and uniform relation between the voltage and current throughout the line. The conditions at each quarter wave-length have been calculated and show clearly the uniform conditions throughout the line.

The changes in the different items are very interesting and can be followed through the table.

The total length of this line, 3100 miles, is sufficient to span this country from the Atlantic to the Pacific.

The table shows that such a line could be operated with practically unity-power factor throughout. With 200,000 volts at the receiving end it would require only 256,300 volts at the generating end. This would

TABLE IV

OPERATING CHARACTERISTICS OF VERY LONG COPPER TRANSMISSION LINE AT UNIFORM POWER FACTOR

General Data

Nominal line voltage	220,000 Volts	Resistance per mile at 20 deg. cent., 98 per cent Conductivity	0.0558 Ohms
Frequency	60 Cycles	Reactance per mile	0.791 Ohms
Conductor, copper, stranded	1,000,000 Cir. Mils.	Susceptance " "	5.38 Micro-mhos.
" diameter	1.152 Inches	$\sqrt{L/C} = 383.3$	
Spacing—flat	20 Feet		

There will be no corona at nominal voltage. In the calculations it has been assumed that there is no leakage loss.

Item	Point 1 Receiving End	Section 1-2	Point 2	Section 2-3	Point 3	Section 3-4	Point 4	Section 4-5	Point 5 Sending End
Section Length (miles)		775		775		775		775	
Total Length (miles)		775		1,550		2,325		3,100	
" " (wave lengths)		¼		½		¾		1	
Volts (delta)	200,000		212,700		226,400		240,700		256,300
" (Y)	115,500		122,790		130,730		139,080		148,030
Angle with Potential at Point 1* (degrees)	0		92.09 *d*		184.17 *d*		276.26 *d*		368.34 *d*
Load kv-a. (total)	104,400		118,110		133,740		151,290		171,600
" kw. "	104,340		118,050		133,680		151,200		171,510
" kv-a. (per phase)	34,800		39,370		44,580		50,430		57,200
" kw. " "	34,780		39,350		44,560		50,400		57,170
Current (amperes)	301.2		320.6		341.0		362.9		386.2
Power Factor*	0.9994 *d*		0.9994 *d*		0.9994 *d*		0.9994 *d*		0.9994 *d*
Angle (degrees)*	2.02 *d*		2.02 *d*		2.03 *d*		2.02 *d*		2.03 *d*
Critical load (kv-a.)	104,400		118,000		133,900		151,050		171,500
Line Loss (kw.) (total)		13,710		15,630		17,520		20,310	
" " " (per phase)		4,570		5,210		5,840		6,770	
Line Drop (volts) (delta)		12,630		13,750		14,460		15,500	
" " " (Y)		7,290		7,940		8,350		8,950	
Per Cent Line Loss (section)		13.14		13.24		13.12		13.43	
" " " " (total)		13.14		28.13		44.9		64.4	
" " " Drop (section)		6.31		6.47		6.39		6.43	
" " " " (total)		6.31		13.2		20.4		28.1	

**d* = leading; *g* = lagging.

TABLE V

OPERATING CHARACTERISTICS OF VERY LONG COPPER TRANSMISSION LINE

General Data

Nominal Line Voltage	220,000 Volts	Resistance per mile at 20 deg. cent., 98 per cent Conductivity	0.0558 Ohms
Frequency	60 Cycles	Reactance per mile	0.791 Ohms
Conductor, copper, stranded	1,000,000 Cir. Mils.	Susceptance " "	5.38 Micro-mhos
" diameter	1.152 Inches	$\sqrt{L/C} = 383.3$	
Spacing—flat	20 Feet		

There will be no corona at nominal voltage. In the calculations it has been assumed that there is no leakage loss.

Item	Point 1 Receiving End	Section 1-2	Point 2	Section 2-3	Point 3	Section 3-4	Point 4	Section 4-5	Point 5 Sending End
Section Length (miles)		775		775		775		775	
Total Length (miles)		775		1,550		2,325		3,100	
" " (wave lengths)		¼		½		¾		1	
Volts (delta)	200,000		212,700		226,300		241,100		256,200
" (Y)	115,500		122,790		130,660		139,200		147,920
Angle with Potential at Point 1 (degrees)*	0		94.00 *d*		184.38 *d*		277.97 *d*		368.75 *d*
Load kv-a. (total)	104,400		118,000		133,920		151,500		171,720
" kw. "	104,200		118,000		133,650		151,500		171,300
" kv-a. (per phase)	34,800		39,330		44,640		50,500		57,240
" kw. " "	34,730		39,330		44,550		50,500		57,100
Current (amperes)	301.2		320.2		341.4		362.6		386.8
Power Factor*	0.9975 *d*		1.0000 *d*		0.9980 *d*		1.0000 *d*		0.9985 *d*
Angle (degrees)*	4.04 *d*		0.23 *d*		3.62 *d*		0.63 *d*		3.22 *d*
Critical Load (kv-a.)	104,400		118,000		133,800		151,700		171,300
Line Loss (kw.) (total)		13,800		15,660		17,850		19,800	
" " (kw.) (per phase)		4,600		5,220		5,950		6,600	
" Drop (volts) (delta)		12,700		13,600		14,800		15,100	
" " " (Y)		7,290		7,870		8,540		8,720	
Per Cent. Line Loss (section)		13.25		13.30		13.35		13.06	
" " " " (total)		13.25		28.3		45.4		64.4	
" " " Drop (section)		6.31		6.41		6.53		6.26	
" " " " (total)		6.31		13.13		20.5		28.1	

**d* = leading; *g* = lagging.

then indicate that by designing a line properly in relation to its critical load it is now possible to transmit at any commercial frequency many times as far it would be commercially practical to do so.

It must be noted particularly that the results in this table are for full load only and are not set forth to show the operation of a line with variable load. With such a line as this it would be necessary from a financial point of view to keep the line operating at 100 per cent load factor so that light load conditions need not be considered. It would be necessary to consider how to get such a line into service, but this could be accomplished in a number of ways if the line were otherwise commercially feasible.

Table V shows a line in every way similar to that in Table IV except that the load power factor is slightly more leading, being the same as Table II for flat voltage. Table V shows that with this longer line there is practically no difference in the voltage drop. The effect of the flat voltage on the first 200 miles of the line being overcome by the greater drop in the remainder of the 775 miles. Table V does show the variation of the phase angle from side to side of the stable angle of 2.02 degrees used in Table IV.

To visualize the results of Tables IV and V better they have been plotted in Fig. 8. Near the top the vector position at five points on the line is given showing plainly the complete revolution through the length. Yet, at each point the current and voltage are practically in phase. The voltage, current and load rise almost uniformly from the sending end to the receiving end. The power factor curves show the uniform power factor predicted and calculated in Table IV, and the oscillating power factor of Table V gradually

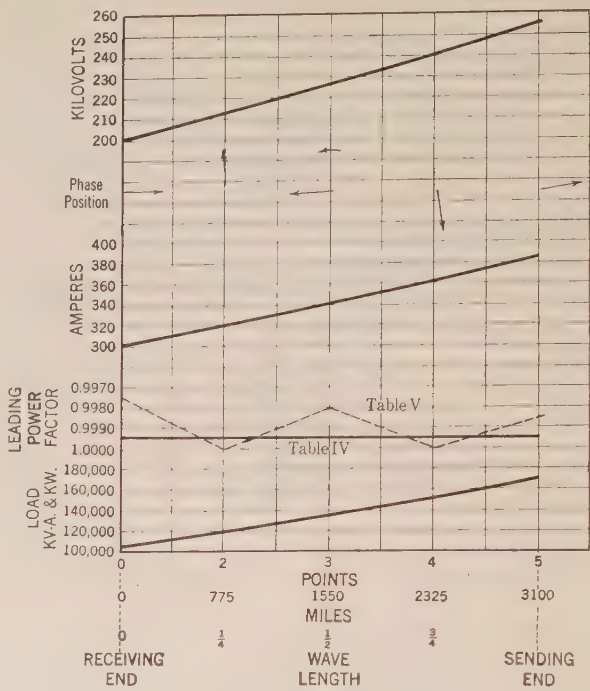


Fig. 8—Operating Characteristics of Very Long Copper Transmission Line

approaching the uniform value of Table IV. The very large scale used for the power factor should be appreciated for the variation is really very slight.

TABLE VI

OPERATING CHARACTERISTICS OF VERY LONG ALUMINUM TRANSMISSION LINE

General Data

Nominal Line Voltage	220,000 Volts	Resistance per mile at 75 deg. Fah., 62 per cent Conductivity	0.179 Ohms
Frequency	60 Cycles	Reactance per mile	0.833 Ohms
Conductor, aluminum, stranded	500,000 Cir. Mils.	Susceptance " "	5.09 Micro-mhos.
" diameter	0.81 Inch	$\sqrt{L/C} = 405$	
Spacing—flat	20 Feet		

There will be no corona at nominal voltage. In the calculations it has been assumed that there is no leakage loss.

Item	Point 1 Receiving End	Section 1-2	Point 2	Section 2-3	Point 3	Section 3-4	Point 4	Section 4-5	Point 5	Section 5-6	Point 6 Sending End
Section Length (miles)		775		775		775		775		775	
Total Length (miles)		775		1,550		2,325		3,100		3,875	
" " (wave lengths)		¼		½		¾		1		1¼	
Volts (delta)	120,000		143,400		170,100		200,000		239,100		279,500
" (Y)	69,300		82,800		98,200		115,500		138,100		161,470
Angle with Potential at Point 1* (degrees)	0		76.78 *d*		176.26 *d*		262.17 *d*		359.62 *d*		448.23 *d*
Load kv-a. (total)	35,940		50,040		70,260		98,800		138,300		193,800
" kw. "	35,340		47,610		70,200		96,540		138,300		191,100
" kv-a. (per phase)	11,980		16,680		23,420		32,930		46,100		64,600
" kw. " "	11,780		15,870		23,400		32,180		46,100		63,700
Current (amperes)	172.9		201.5		238.5		285.2		334.0		400.0
Power Factor*	0.983 *g*		0.951 *d*		0.9991 *g*		0.9773 *d*		0.9995 *d*		0.9870 *d*
Angle between Current & Potential (degrees)*	10.67 *g*		18.05 *d*		2.46 *g*		12.13 *d*		1.77 *d*		9.09 *d*
Critical Load (kv-a.)	35,500		50,800		71,500		98,800		141,200		193,000
Line Loss (total) (kw.)		12,290		22,590		26,400		41,700		52,800	
" " (per phase) (kw.)		4,090		7,530		8,800		13,900		17,600	
Line Drop (volts) (delta)		23,400		26,700		29,900		39,100		40,400	
" " " (Y)		13,500		15,400		17,300		22,600		23,370	
Per Cent. Line Loss (section)		34.7		47.4		37.6		43.2		38.2	
" " " " (total)		34.7		98.7		173.0		291.0		441.0	
" " Line Drop (section)		19.5		18.6		17.6		19.6		16.9	
" " " " (total)		19.5		41.7		66.6		99.3		133.0	

**d* = leading; *g* = lagging.

Characteristics of Very Long Aluminum Line: The line drop and losses were so low for the copper line that an extra long aluminum line has been calculated to reach more quickly the conditions that might obtain with a copper line 10,000 or 15,000 miles long. Table VI shows the operating characteristics of this very long aluminum transmission line. This is in every way similar to Table V except that the length has been extended to a total of 3875, being 1¼ wave-lengths. The conditions were not chosen for constant power-factor but so that "Point 4" with 200,000 volts would correspond to "Point 1" of the copper line in Table V, and the aluminum line in Table III for "predicted flat voltage." This again shows that the flat voltage condition cannot be extended for a great length of line due to the power losses; the effort to do this just causes a swinging of the power factor. The decrease of swing of the power factor as the sending end is approached is evident; the angle for stable operation is 6.06 degrees.

Conclusion

The formula for the critical load and various rules for its use were set forth at the beginning of the paper and therefore will not be repeated here.

It is undoubtedly possible that the form of expression of the rules can be improved and considerably extended. It is therefore hoped that this paper will not only lead many to a better conception of what is going on in a high-tension transmission line, but will also lead them to develop and present their thoughts so that others may have the benefit of a further practical understanding of the nature of transmission of electrical energy.

Included in the paper are examples of very long transmission lines to show how their action may be predicted, rather than as examples of economical lines for any particular condition.

It must be remembered that while approximate results can be obtained in some cases that the formulas are *not* approximate formulas but for the purpose of obtaining quickly in advance of accurate calculations a "Qualitative Analysis of Transmission Lines."

THEORETICAL ADVANTAGES OF ELECTRIC MELTING OF BRASS

The theoretical advantages of electric brass melting are summarized by the United States Bureau of Mines as follows: (1) Melting may take place in a neutral or reducing atmosphere, thus minimizing loss of metal by oxidation and improving the quality of the product through freedom from oxides; (2) Metal of crucible quality may be obtained without the use of crucibles; (3) Melting may take place in a tightly closed chamber, or at least in one free from the constant passage of the products of combustion of fuel, and thus losses of volatile metals such as zinc and lead may be reduced. Contamination by sulphur from fuel is avoided; (4) In some types of electric furnaces the temperature may be more readily controlled than in fuel-fired furnaces; (5) In some types of furnaces the molten metal is thoroughly stirred, thus giving a uniform product, even with large heats; (6) There is no handling or storage of fuel, such as coke, coal, or oil, and no ashes have to be removed. The cost of power can be accurately predicted over longer periods than the cost of fuel; (7) Working conditions about the furnaces are less dangerous to health and safety of workmen, provided suitable types of furnaces are chosen; (8) The above advantages may be obtained in furnaces of larger capacity than can be used satisfactorily in the fuel-fired crucible types, with resulting greater uniformity of product, lower labor cost, and increased production.

FURTHER INTERCONNECTION IN MASSACHUSETTS

Plans have been completed and construction work is about fifty per cent finished on an 110,000-volt, double-circuit, steel-tower line from Turners Falls, Mass. to Pittsfield, Mass., a distance of approximately thirty-seven miles. This line will interconnect the system of the Turners Falls Power & Electric Company and the Pittsfield Electric Company.

The former company operates a 55,000-kw. hydroelectric development at Turners Falls and distributes power over four 66,000-volt circuits from Turners Falls through the central part of Massachusetts, supplying all the central stations in the Connecticut Valley in Massachusetts except Holyoke, and wholesaling power direct to most of the larger industries. The company also operates a 30,000-kw. steam plant located on the Connecticut River, near Chicopee, Mass., and is interconnected with the United Electric Light Company at Springfield and the New England Power Company at Leverett, Mass.

The Pittsfield Electric Company produces practically all of its power in a steam plant at Pittsfield and supplies power to most of the other distributing companies and industries in the Housatonic Valley in Western Massachusetts. The construction of this line creates the first entrance of modern high-tension transmission facilities into the district supplied by the Pittsfield Electric Company, and makes it a part of the now nearly complete interconnection which exists in Massachusetts from one end of the State to the other.

The design and construction of this line will be such as to meet amply all the power requirements of the Housatonic Valley, with plenty of spare capacity, for many years to come, relieving that district of the necessity of developing large steam plants in a territory not particularly suited for such developments. The entire line will be of the same heavy construction used on the other transmission lines of the Turners Falls Power & Electric Company, all of which passed through New England's great sleet storm of November, 1921 without the failure or distortion of a single tower.

The line will be operated at the start at 66,000 volts, although the equipment at each end and the design and insulation of the towers will be suitable for operation at 110,000 volts. The first few towers at each end of the line are designed for carrying four circuits, two at 110,000 volts and the other two at any distribution voltage not over 20,000 volts. This gives an opportunity of carrying 20,000-volt distribution circuits out from the station at each end through the congested communities to the open country. The circuits will be of 2/0 copper and arrangements will be made for melting ice off the conductors in case of sleet storms by the passage of relatively low-voltage current over the line when necessary.

Another Harmonic Analyzer

BY F. S. DELLENBAUGH, Jr.,

Member A. I. E. E.
Secretary Research Division, Electrical Engineering Department
Massachusetts Institute of Technology.

Review of the Subject.—*Modern alternating-current engineering involves the necessity of frequently analyzing curves for harmonics. All of the methods of analysis have more or less serious objections. A method based upon the averaging of ordinates selected at the proper intervals has been developed into a machine which is reasonably simple and cheap to construct and can be operated without great skill. The machine depends chiefly for its operation upon a bar containing notches at the proper intervals and each bar is suitable for curves of the same plotted wave length. It is thus limited to curves plotted with the same scale of abscissas, but different bars may be manufactured for different scales and the machine thus adopted to various types of curves. A comparison with the times required for harmonic analysis by different methods shows that it compares favorably with other devices.*

CONTENTS

While working in the Research Division laboratory at Massachusetts Institute of Technology, Mr. David O. Woodbury devised an extremely simple and useful harmonic analyzer, which is thought worth describing as it can be made to analyze harmonics of very high order without the usual attendant exhaustion suffered by the investigator. It is also rapid for harmonics of any order, simple to build, and while it is limited to curves having the same length of base for one period, it can be fitted to any size of curve by merely making a new bar, which must be accurately machined, but is not complicated or expensive.

The theory of harmonic analysis has been gone into very thoroughly in many text books and will not be here repeated. For bibliography the reader is referred to the A. I. E. E. Journal, Vol. XL, p. 135, 1921. The analyzer being described utilizes the method of selected ordinates, originally proposed by Houston-Kennelly, and developed in detail by Fischer-Hinnen. The curve must be divided into a different number of portions for each harmonic, the number of parts being the same as the order of the harmonic, In this way the sine or cosine multipliers of the usual schedule form become unity (or zero) and the value of the coefficient for the particular harmonic may be obtained by simply averaging ordinates at the different points given by the division of the curve into parts. This may be expressed as follows:

For Odd Harmonics Only (180 Deg. of Curve Required)

If, starting at $X = 0$, we measure n ordinates at intervals of π/n, the average of these ordinates taken alternately plus and minus is equal to the sum of the amplitudes of the nth, 3nth, 5nth............*Cosine components.*

If, starting at $X = \pi/2n$, we measure n ordinates at intervals of π/n the average of these ordinates taken alternately plus and minus is equal to the sum of the amplitudes, taken alternately plus and minus, of the nth, 3nth, 5nth........*Sine components.*

For Both Odd and Even Harmonics. (360 Deg. of Curve Required)

If, starting at $X = 0$, we measure $2n$ ordinates at intervals of π/n, the average of these ordinates taken alternately plus and minus is equal to the sum of the amplitudes of the nth, 3nth, 5nth,..........*Cosine components.*

If, starting at $X = \pi/2n$, we measure $2n$ ordinates at intervals of π/n, the average of these ordinates taken alternately plus and minus is equal to the sum of the amplitudes, taken alternately plus and minus, of the nth, 3nth, 5nth........*Sine components.*

Construction of Analyzer

The analyzer consists in principle of a bar which is free to move in the direction of ordinates but fixed in the direction of abscissas. This bar contains a series of notches spaced 1/3rd, 1/5th or any interval of π/n for a distance equal to the length of curve necessary to explore for analysis. By rotating the bar any series of notches may be brought uppermost. An index carrying cross lines slides upon this bar and bears a spring-operated dog, which drops into the notches sufficiently to locate the position of the index, but lightly enough so that it may be pushed along without effort. The carriage upon which the bar is mounted has a magnetic clutch which engages a scale, the motion being imparted to the scale by the magnetic clutch, and a brake preventing motion of the scale when the circuit of the magnetic clutch is open. If the curve to be analyzed is now placed upon a platen under the index the procedure given in the rules quoted above may be followed mechanically by merely moving the index from notch to notch, bringing the cross lines into alinement with the curve for each position, and properly operating the magnetic clutch so that the respective ordinates are alternately added and subtracted upon the scale. The scale reading will then give the sum of the nth, 3nth, 5nth, etc. harmonic coefficients.

The mechanism may obviously be made either to

have a sliding motion in a plane or rotate around centers. A sketch of an early model operating upon the first principle is shown in Fig. 1. The scale is a steel rule laid across the top. The magnetic clutch is merely an old bell magnet running on two round rods. This particular machine was arranged to take a cardboard template of the curve, the motion being imparted to the clutch by a small roller following the template. The clutch was operated by a contact roller traveling

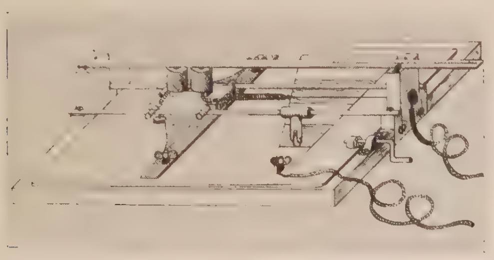


FIG. 1—EARLY MODEL OF WOODBURY ANALYZER

The template under roller at right hand side of base is changed for each harmonic.

over a specially prepared plate with alternate spaces of insulation and metallic conductor, which took the place of the notched bar. Different plates were used for each order of harmonic. This machine was intended to be practically automatic so that the roller was dragged over the curve template slowly and the coefficient read off the scale after each traverse. Mechanical difficulties made this type impractical, so an improved model was made, the parts swinging around centers. This is shown in Figs. 2 and 3.

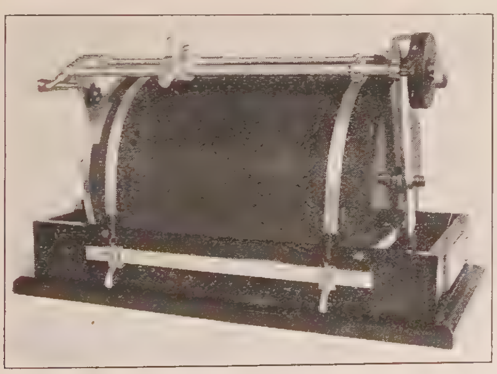


FIG. 2—FRONT VIEW OF FINAL MODEL OF WOODBURY ANALYZER

The scale upon which the coefficients are read may be seen abutting the left hand end of cylindrical platen.

The curve is clamped upon the cylindrical platen by means of the two bands. The notching bar may be seen with the setting head upon the right hand end, Fig. 2. The index with cross lines does not show plainly but is carried upon the forward part of the carriage riding upon the notching bar and plain guide bar. The magnetic clutch is attached to the left hand radius supporting arm, showing in right hand end of Fig. 3, and the scale is adjacent to the left hand end of the cylindrical platen almost in contact with clutch. The index for the scale is attached to the left hand side of platen, Fig. 2, and the brake is within the box and may be adjusted by the thumb screw shown in Fig. 3 under right hand strap. The clutch is operated by a switch in the handle upon the left hand radial supporting arm, Fig. 2.

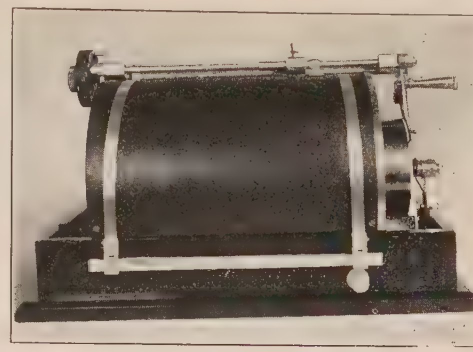


FIG. 3—REAR VIEW OF FINAL MODEL OF WOODBURY ANALYZER

The small cylindrical drum at the right is the magnetic clutch. The thumb screw under right hand strap is the brake adjustment to prevent slipping of scale.

OPERATION OF ANALYZER

To perform the analysis, a notching bar matching the curve to be analyzed is placed in the machine. If the curves are many different scales this, of course, is a serious objection as they must be reduced to the same scale, but if oscillograms are made with a synchronous film drive, or if the curves are plotted by hand from tabular data, the scale can be always made the same and therefore one bar is sufficient unless very many harmonics are desired. The development

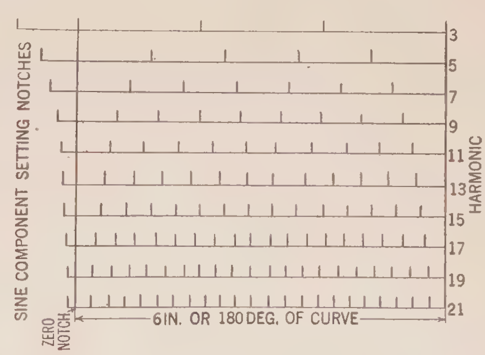


FIG. 4—DEVELOPMENTS OF NOTCHING BAR FOR ODD HARMONICS UP TO 21ST

of the notching for a bar to be used in analyzing a curve with a scale of 6 in. = 180 deg. covering odd harmonics from the 3rd to the 21st is shown in Fig. 4, and the bar may be constructed out of half inch stock.

The curve is next adjusted so that its axis is parallel to the notching bar, readily determined by sliding the index with the bar fixed, and the index adjusted so that when the dog is in the zero notch, the cross lines correspond with the zero point on the curve. The index is mounted upon a sleeve sliding within the carriage

for this purpose, which is fastened by a set screw when in the right place. The setting head is then turned to the harmonic desired and the carriage moved until the dog falls in the first notch to right of zero. The index is then registered with the curve, the magnetic clutch switch closed, the index then moved until the dog falls into the next notch, registered with the curve, and the clutch switch released. The carriage is then moved to the next notch and the same sequence repeated. With a small amount of practise this manual sequence of events becomes practically automatic and the analysis will proceed as swiftly as it is possible to slide the carriage from notch to notch. The reading upon the scale will then be the sum of the amplitudes of the nth, 3nth, 5nth, etc. *Cosine terms.*

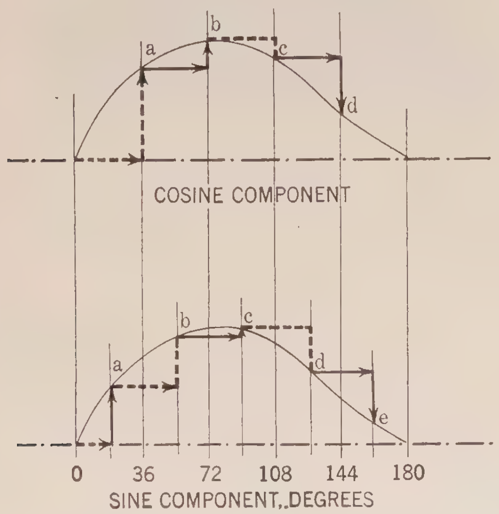


FIG. 5—THE HEAVY LINE SHOWS THE TRAVEL OF ANALYZER INDEX.

During the solid portions the clutch switch is closed and during the dotted portions the clutch is released. Any path may be followed by the index between the points of the curve A. B. C, etc. These points are located by the notching bar.

The scale of the result depends upon the divisions made upon machine and reads direct in inches or centimeters. For the *sine* terms the carriage is moved to the special setting notch shown in Fig. 4, to the left of the zero notch, the index set screw is loosened, the index set to the zero of the curve, the carriage moved to the zero notch, and then a similar procedure to that for the cosine term followed. The motion of the index and the closing of the clutch switch for the 5th harmonic is indicated diagrammatically in Fig. 5. The results can be figured in per cent of fundamental, or if scale of curve is known, they can be readily transferred to terms of the function represented.

The fundamental is obtained from the values of the harmonics and from a few specially read ordinates. The following equations show how this is done:

BOTH ODD AND EVEN HARMONICS

$$Y_0 = b_0 + b_1 + b_2 + b_3 \ldots\ldots$$

Hence $b_0 = Y_0 - (b_1 + b_2 + b_3 \ldots\ldots)$

$$1/2\,(Y_0 - Y_{180}) = b_1 + b_3 + b_5 \ldots\ldots$$

Hence $b_1 = 1/2\,(Y_0 - Y_{180}) - (b_3 + b_5 \ldots\ldots)$

$$1/2\,(Y_{90} - Y_{270}) = a_1 - a_3 + a_5 - a_7 \ldots\ldots$$

Hence $a_1 = 1/2\,(Y_{90} - Y_{270}) - (-a_3 + a_5 - a_7 \ldots)$

ODD HARMONICS ONLY

$$b_0 = 0$$

$$Y_0 = b_1 + b_3 + b_5 + b_7 \ldots\ldots = 0$$

Hence $b_1 = -(b_3 + b_5 + b_7 \ldots\ldots)$

$$Y_{90} = a_1 - a_3 + a_5 - a_7 \ldots\ldots$$

Hence $a_1 = Y_{90} - (-a_3 + a_5 - a_7 \ldots\ldots)$

In order to interpret the results it is convenient to have a chart or table in which the readings may be inserted, as otherwise the proper signs, additions and subtractions may become confused. Charts of this sort are shown in Tables I, II and III for both odd and even harmonics.

CONCLUSIONS

While this analyzer requires intelligent operation and is not fully automatic, it offers the advantages of simplicity, ease of construction, and rapidity of operation. It also frees the operator from the extremely wearisome amount of multiplication, addition and subtraction required by any extensive analysis with the usual schedule methods, and any one reading may be checked in a few moments without going through a series of calculations. With similar curves, as for instance the magnetizing current of a transformer at different densities, where the general character of the analysis is well known, but the actual magnitudes of the harmonics are desired, very great speed may be obtained, about five minutes being required for the determination of the third, fifth, seventh and ninth harmonics. Table I shows some comparative times required. The accuracy is about the same as that obtained by schedule analysis unless a large number of ordinates is used. In a number of test analyses of curves of known composition, or by comparison with other methods of analysis an average maximum error of about 2 per cent was found, the error being expressed in per cent of the amplitude of the fundamental. With some types of curves slightly larger errors may occur. If the notching bar is carefully constructed the only chance for mechanical errors lies in the slipping of the clutch or dragging of the scale, and as the adjustment of these parts is simple and not at all critical this can not readily occur. Recently in the Research Division Laboratories analysis of all odd harmonics up to and including the 41st were made quite easily, the time required not being measured, but being far less than that necessary for any computational method, and the personal wear and tear being negligible instead of extreme. In general it might be stated that for certain classes of work this analyzer is extremely convenient and can be easily manufactured. It still is not the ideal analyzer but must be used with an understanding of its limitations, under which conditions it is very satisfactory.

TABLE I

TABULATION OF ANALYZER DATA

For Odd and Even Harmonics and Constant Term

Cosine Coefficients

Order of Harmonic	Analyzer Reading	Divide Reading by	Giving	Then Subtract	Net Harmonics		Sum for b_1
					+	−	
b_2		4		$b_6 + b_{10}$			—
b_3		6		b_9			$+ b_3 =$
b_4		8		b_{12}			—
b_5		10		*			$+ b_5 =$
b_6		12		*			—
b_7		14		*			$+ b_7 =$
b_8		16		*			—
b_9		18		*			$+ b_9 =$
b_{10}		20		*			—
b_{11}		22		*			$+ b_{11} =$
b_{12}		24		*			—

Sum (B) = ...

*If known harmonics present greater than 12th subtract $b_{3nth} + b_{5nth}$ etc.

Sine Coefficients

Order of Harmonic	Analyzer Reading	Divide Reading by	Giving	Then Subtract	Net Harmonics		Sum for a_1
					+	−	
a_2		4		$-a_6 + a_{10}$			—
a_3		6		$-a_9$			$- a_3 =$
a_4		8		$-a_{12}$			—
a_5		10		*			$+ a_5 =$
a_6		12		*			—
a_7		14		*			$- a_7 =$
a_8		16		*			—
a_9		18		*			$+ a_9$
a_{10}		20		*			—
a_{11}		22		*			$-a_{11}$
a_{12}		24		*			—

Sum (A) = ...

*If known harmonics present greater than 12th subtract $- a_{3nth} + a_{5nth}$ etc.

Y_0 = ... $\quad b_0 = Y_0 -$ Sum B

Y_{90} = ... $\quad b_1 = 1/2\ (Y_0 - Y_{180}) -$ Sum B

Y_{180} = ... $\quad a_1 = 1/2\ (Y_{90} - Y_{270}) -$ Sum A

Y_{270} = ...

Note: Y_0, Y_{90}, Y_{180}, etc. means the values of ordinates at 0 deg., 90 deg., 180 deg., etc.

Equation of curve then:—

$$Y = b_0 + a_1 \sin \theta + a_2 \sin 2\theta + a_3 \sin 3\theta + a_4 \sin 4\theta \ldots\ldots$$
$$+ b_1 \cos \theta + b_2 \cos 2\theta + b_3 \cos 3\theta + b_4 \cos 4\theta \ldots\ldots$$

TABLE II

TABULATION OF ANALYZER DATA

For Odd Harmonics Only

Cosine Coefficients

Order of Harmonic	Analyzer Reading	Divide Reading by	Giving	Then Subtract	Net Harmonics	
					+	−
b_3		3		$b_9 + b_{15}$		
b_5		5		b_{15}		
b_7		7		*		
b_9		9		*		
b_{11}		11		*		
b_{13}		13		*		
b_{15}		15		*		
b_{17}		17		*		

Sum (B) = ...

*If known harmonics present greater than 12th subtract $b_{3nth} + b_{5nth}$. etc.

TABLE II—(*Continued*)

Sine Coefficients

Order of Harmonic	Analyzer Reading	Divide Reading by	Giving	Then Subtract	Net Harmonics		Sum for a_1
					+	−	
a_3		3		$-a_9 + a_{15}$			$- a_3 =$
a_5		5		$-a_{15}$			$+ a_5 =$
a_7		7		*			$- a_7 =$
a_9		9		*			$+ a_9 =$
a_{11}		11		*			$- a_{11} =$
a_{13}		13		*			$+ a_{13} =$
a_{15}		15		*			$- a_{15} =$
a_{17}		17		*			$+ a_{17} =$

Sum (A) = ...

*If known harmonics present greater than 12th subtract $b_{3nth} + b_{5nth}$ etc.

Y_{90} = ... $\quad b_1 = -$ Sum B

$\quad a_1 = Y_{90} -$ Sum A

Note Y_{90} means value of ord. at 90 deg.

Equation of curve:—$Y = a_1 \sin \theta + a_3 \sin 3\theta + a_5 \sin 5\theta \ldots\ldots\ldots$

$+ b_1 \cos \theta + b_1 \cos 3\theta + b_5 \cos 5\theta \ldots\ldots\ldots$

TABLE III

COMPARISON OF TIME REQUIRED FOR HARMONIC ANALYSIS BY DIFFERENT METHODS

Method	Time	No. Harmonics solved	Minutes per Coeff.	Authority
Steinmetz..........	10 hr.	10	60.00	D. C. Miller
Schedule..........	3 hr.	8	22.5	D. C. Miller
Schedule..........	1 hr.	8	7.5	F. W. Grover
Schedule..........	2.5 hr.	17	10.6	Dellenbaugh
Schedule..........	15 min.	3	5.0	D. C. Miller
Coradi Mch........	13 min.	10	1.3	D. C. Miller
Coradi Mch........	7 min.	5	1.4	D. C. Miller
Schedule..........	30 min.	6	5.0	Dellenbaugh
Electric Mch.......	3.5 min	6	0.6	Dellenbaugh
Woodbury Mch.	5 min.	3	1.7	Dellenbaugh
Woodbury Mch.....	4.6 min.	3	1.5	Woodbury
Woodbury Mch.....	9.75 min.	6	1.63	Woodbury
Schedule..........	7 min	3	2.3	Woodbury
Schedule..........	22 min.	6	3.7	Woodbury

BIBLIOGRAPHY AND PATENTS ON ELECTRICAL INSULATING MATERIAL

In connection with the Bureau's investigation of the properties of certain types of electrical insulating materials, a rather comprehensive bibliography of papers, books, and periodicals has been prepared.

An examination of the U. S. patents covering insulating materials and methods of manufacture, and particularly materials of the phenolic type, has also been made, and a list of the more important U. S. patents issued prior to September, 1920, was completed.

Since a considerable demand has arisen for copies of these, they have been issued in mimeographed form as Letter Circulars Nos. 50 and 51 "Bibliography of books and titles of periodicals on properties and uses of insulating materials" and "Lists of the more important U. S. patents covering the materials and methods of manufacture of an insulating material." Only a limited supply of these two letter circulars is available, but a copy will be sent on request, as long as the supply lasts, to any person who can show an actual need for them.

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

ARTIFICIAL LIGHTING COMPETES WITH DAYLIGHT

A novel lighting installation was recently made under a bridge of the New York, New Haven and Hartford Railroad in Providence, R. I. A street extends a considerable distance under this bridge with the result that it appears very dary dark to the automobilists in going from the brightly sunlighted street to the darkened street beneath the bridge; then again on leaving the darkened area under the bridge and coming out into sunlight, the drivers were blinded, creating extreme discomfort and endangering the safety of the public.

For ordinary illumination at night, lamps of small size were sufficient to light the roadway, but in order to relieve the contrast between the sunlight and the dark area under the bridge, a higher level of illumination was necessary. This fact resulted in the installation

Artificial Lighting Competes with Daylight

of a system of units with 1000 watt lamps, which brought the illumination to a level which greatly relieved the effect of contrast. The new lighting system is now in operation during the entire day providing greater comfort and safety to the drivers and pedestrians who travel on this street.

Several other installations of this sort, but on a smaller scale have proved successful. A similar scheme has been been planned for the New York-New Jersey-Hudson River vehicular tunnel, by which the transition from daylight to the tunnel lighting is made gradual.

A FOCUSING FLASHLIGHT

A new focusing type of flashlight capable of throwing a beam of 200 to 300 feet greatly enlarges the scope of usefulness of this popular type of portable lighting unit.

The development of the concentrated filament flashlight lamp has made possible the new focusing type flashlight. The filament is a fine coil of tungsten wire, which on account of its short length requires the most advanced methods of the lamp manufacturer's art. In one popular unit the flashlight is provided with a polished parabolic reflector fixed in position, and the lamp is screwed into a movable socket which allows the lamp filament to be placed at the focus of the reflector by adjustment of the threaded-end cap which holds the battery in place. Exact adjustment of the lamp filament is easily secured and a beam of high intensity and narrow spread results.

Fig. 1

Three Types of Focusing Flashlights

Fig. 2 shows a cross-section of one popular unit. Either flat or curved glass cover lenses serve to keep out dirt and moisture; the concentrated beam of light is obtained with the parabolic reflector and the very small source. A receptacle is provided in the end cap for holding one or two extra lamps.

Delivery men and automobile drivers find it an invaluable aid in observing house numbers and locating areas beyond range of flashlights heretofore available. For the hunter or camper it fills the need for a high intensity light that can be used at long range.

Fig. 2

Mechanism of One Type of Focusing Flashlight.

Spring *A* holds lamp socket-holder *B* against end of battery at *C* screwing end cap *D* forces battery against lamp socket-holder, thus changing the position of lamp with respect to the parabolic reflector. Note extra lamp in bottom cap.

BURNING CHRISTMAS TREE LAMPS IN MULTIPLE

No little disappointment and inconvenience is often caused by the burning out of one lamp of a series-connected Christmas tree lighting set, resulting in the darkening of all of the lamps. The defective lamp is sometimes found only after testing all of the lamps on the tree. This sometimes involves considerable trouble. A transformer designed for use with Christmas tree lighting sets and with electrical toys, eliminates these difficulties by permitting the lamps to operate in multiple.

This transformer can be used on 100-120 volt alternating current circuit and has a maximum capacity of about 70 watts. Taps for 5, 14, and 19 volts are available on the transformer, the Christmas tree lamps

requiring the 14-volt tap. The three taps allow a variation of voltage so that the transformer can be used to operate electric toys thereby enlarging its scope of usefulness beyond the Christmas season.

A complete outfit is available consisting of the transformer with 10-foot lead and plug for attaching to a convenience outlet or lamp socket, 43 feet of cord with

A Step-Down Transformer for Use in Burning Christmas Tree Lamps in Multiple

17 sockets attached, and eighteen 14-volt Mazda lamps, one lamp being a spare, all packed in a distinctive holiday box.

The 10-foot lead permits the transformer to be concealed beneath the tree. The cord which carries the sockets is divided into branches in sets of four at 15-inch intervals allowing adequate distribution of the lamps to all parts of the tree. The lamps are the regular Mazda Christmas tree lamps, and are supplied in red, blue, green, orange, and frosted white.

This Phantom View Shows How the Wiring of the Christmas Tree Lighting Set Permits the Lamps to be Distributed to all Parts of the Tree

COLOR MATCHING UNITS IN THE INDUSTRIES

It is the opinion of a great many persons acquainted generally with color matching units that these units find their greatest field of application in commercial establishments. While it is true that these units, when first introduced about eight years ago, found immediate favor for color matching purposes in many department stores, haberdashery shops, millinery shops and furriers, it is nevertheless true that these units have their widest application today in locations commonly classed as industrial. To be convinced of this fact, and to obtain a greater appreciation, perhaps, of the possibilities of color matching units from the various standpoints of service to industry, to science, to the arts, etc., one need only examine a classified list of present-day users of these units:—

Art Schools	Jewelers
Museums and Galleries	Laboratories
Banks	Leather Manufacturing Plants
Cigar Stores and Factories	Men's Furnishers
Clothing Manufacturers	Tailors and Haberdashers
Coffee Roasting Rooms	Milliners
Dentists and Dental Supply Manufacturers	Paint, Color and Dye Works
Department and Dry Goods Stores	Paper Mills
Dyers and Cleaners	Printers and Lithographers
Food Products	Rubber Manufacturing Plants
Furriers	Schools and Colleges
Grain Elevators and Mills	Seed Companies
Hospitals	Shoe Manufacturers
Industrial and Manufacturing Plants	Sugar Refineries
	Textile Mills
	Wall Paper Companies

It will be seen from this list that the field for the advantageous use of these units is wide indeed, and additional uses for them are being discovered, literally, almost every day. Viewed from a strictly engineering standpoint, however, we may say there are at present six clearly defined classes of industrial operations where the color matching unit can not only be used to a good advantage, but where its use is almost necessary. These are as follows:

Lithographing	Leather Grading
Cotton Grading	Dyeing
Cigar Grading	Paint and Chemical Examination

In lithographic printing and in the preparation of lithographic stones for the printing process, the color of the light used for artificial illumination plays a very important part. A large part of lithographing printing is color work, and since the appearance of a given color varies with the quality of light thrown upon it, it is quite essential that in this industry light be used which will show the colors as they appear in daylight. A general system of noon sunlight illumination is also very desirable in the art department. Here, again, over individual desks where accurate color discrimination is essential, north sky daylight units are desirable. For general illumination over the presses, noon sunlight units are to be recommended, one or two units over each press. At those points in the press room where the colors of the finished product are examined and checked, north sky daylight units should be installed. Two well known publishing concerns using artificial daylight units are the Curtis Publishing Co., Philadelphia, which has about 75 north sky daylight units installed near color presses for checking colors, and the Crowell Publishing Co., Springfield, Ohio, where the general illumination of the press room is supplied by about 300 noon sunlight units. Another installation is that in the Bureau of Engraving and Printing, Treasury Department, at Washington, D. C. Several hundred units are used there for general illumination, which are supplemented by many local units of the design shown in Fig. 1 over engravers' benches and tables and at other points where special operations are carried on which require accurate color discrimination.

For the mixing of inks and for other cases where accurate color matching or comparisons are desired, north sky daylight units are recommended. Either pendant units of the type shown in Fig. 1, or angle units having a similar color correcting screen, are used; whether the surfaces illuminated are located in a horizontal or in a vertical plane in most cases, governs the choice of the type of unit.

In practically every large cotton mill, a room is devoted entirely to classifying by tints the cotton which is to be purchased for the mill's use. Likewise, a

Fig. 1—A Unit Which Supplies North Sky Daylight Illumination. Designed Especially for Localized Lighting Where Precision in Color Matching, Grading, Inspection, etc., is Required.

color grading space is imperative in the office of every big cotton buyer and cotton broker. The Bureau of Standards furnishes the standards by which cotton is graded as to tint. Both the primary standards and the secondary or consumer' standards were selected under true north sky daylight conditions. Obviously, if cotton is to be classified by tint with the aid of the standardized "matching samples", correct results can be obtained only when the operation is carried on under north sky daylight itself or its substitute. North sky daylight units give very satisfactory results in this service. Care must be taken, however, to avoid sur-

Fig. 2—A Unit which Supplied Noon Sunlight Illumination. Designed Especially for General Lighting Where Daylight Quality is Required Throughout an Entire Room or Area.

face sheen on the individual strands of the cotton, which may be so great as to give an erroneous impression of its color even though examined under the accurate north sky daylight of the color matching unit. The same problem is presented in the inspection of deep pile silks, velvets, plushes, etc. But in all such cases where the units are properly installed and used, ideal results are obtained.

One of the largest hosiery mills in the country uses color matching units (500-watt units on five-foot centers along the benches) to grade yarns and to match accurately pairs of socks as to color, in order that any slight color differences resulting from the dyeing process will not be noticeable in any one pair.

A great many cigar factories have installed color matching units over the benches where their tobacco inspectors work. North sky daylight units are employed, hung a few feet above the level of the work. Best practise requires one unit for each inspector; if there are many inspectors working side by side along the bench as is usually the case, a unit which takes a 150 or 200-watt Mazda C lamp, will be found satisfactory. This arrangement allows easy, accurate classification by color, not only of the tobacco leaves that are to be used in the manufacture of the different grades of cigars, but also of the finished cigars for separating them into grades according to their color, for packing purposes.

The process of leather grading is also facilitated by the use of these units. In the matching of hides and of finished pieces of leather particularly, it is again necessary to guard against the presence of surface sheen.

Fig. 3—Installation of Color Matching Units in Engraving Department of Lithographing Plant. One Unit with 500-Watt Lamp Installed over each Desk. The Original System of Gas Lamps is Still in Evidence

Color matching units are very desirable and practically a necessity in all high grade dyeing establishments and in certain parts of all plants where fine dyeing is done. They allow accurate duplication of the colors of samples in the minimum length of time. North sky daylight units should be used in the drying rooms and other parts of these establishments where fine discrimination between color tints is imperative.

Most paint manufacturers maintain a laboratory for inspecting and testing the various paints they make. Usually, thin slabs of wood are painted over with the different paints and the colors of these slabs carefully checked. Illumination which will allow accurate color comparison and grouping is very desirable in such locations. Many chemical laboratories, also, require illumination under which slight color changes or the exact color of a precipitation may be noted. The illumination received from color matching units makes it possible to carry on these experiments continuously and accurately.

JOURNAL OF THE American Institute of Electrical Engineers

PUBLISHED MONTHLY BY THE A. I. E. E.
33 West 39th Street, New York
Under the Direction of the Publication Committee

FRANK B. JEWETT, *President*
GEORGE A. HAMILTON, *Treasurer* F. L. HUTCHINSON, *Secretary*

PUBLICATION COMMITTEE
DONALD MCNICOL, *Chairman*
E. E. F. CREIGHTON WM. MCCLELLAN
F. L. HUTCHINSON L. F. MOREHOUSE

GEORGE R. METCALFE, *Editor*

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Phillipines; $10.50 to Canada and $11.00 to all other countries. Single copies $1.00. Volumes begin with the January issue.

Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

The Eleventh Midwinter Convention

NEW YORK, FEBRUARY 14-17

The Eleventh Midwinter Convention of the A. I. E. E. will be held in New York, February 14-17, in the Engineering Societies Building, 33 W. 39th St. The Convention Committee and the Meetings and Papers Committee have cooperated to make this convention one of unusual interest, and the tentative program which contains a number of papers of special merit also includes several instructive and entertaining features.

On Wednesday, the opening day, the morning will be devoted to the registration of members and guests and to meetings of the various A. I. E. E. Committees. The first technical session will be held in the afternoon, the program being under the auspices of the Transmission and Distribution Committee.

The Wednesday evening session will consist of a joint meeting with the Chicago Section by the use of telephone connections and loud speakers. Two papers will be delivered by means of the loud speakers, one being presented at New York and the other at Chicago. Lantern slide illustrations will be shown at both places and a joint discussion will follow. After the telephone meeting an illustrated lecture will be delivered by Mr. William B. Potter who has recently spent several months investigating the electric railway systems of Europe.

On Thursday, the morning session will be devoted to a group of papers on miscellaneous subjects and in the afternoon a technical session, under the auspices of the Telephone and Telegraph Committee, will be held. In the evening there will be a smoker under the auspices of the New York Section of the A. I. E. E., at which moving pictures showing a new development in speech transmission will be exhibited.

The session on Friday morning will be under the auspices of the Electrophysics Committee and on Friday afternoon the final technical session of the Convention will be held under the auspices of the Measurements and Instruments Committee.

On Friday evening the annual dinner-dance will be held and Saturday morning will be devoted to visits of inspection to various engineering works in and about New York City.

The tentative program follows:

TENTATIVE PROGRAM

WEDNESDAY MORNING, FEBRUARY 14

Foyer—11 A. M.

Registration of members and guests.
Committee meetings to be announced.

WEDNESDAY AFTERNOON

2:30 P. M.

TECHNICAL SESSION

Report of Transmission and Distribution Committee, E. B. Meyer, Chairman, Asst. Chief Engineer, Public Service Electric Co., Newark, N. J.

Apparent Dielectric Strength of Cables, by R. J. Wiseman, Okonite Co., Passaic, N. J.

Short-Circuit Currents in Networks, by O. R. Schurig, General Engineering Laboratory, General Electric Company, Schenectady, N. Y.

Qualitative Analysis of Transmission Lines, by H. Goodwin, Jr., Sanderson & Porter, New York, N. Y.

The Heavisidion, by Vladimir Karapetoff, Professor of Electrical Engineering, Cornell University, Ithaca, N. Y.

Cable Testing and Maintenance, by H. S. Phelps, Engineering Dept., and E. D. Tanzer, Transmission Dept., Philadelphia Electric Co., Philadelphia, Pa.

WEDNESDAY EVENING

8:30 P. M.

NEW YORK-CHICAGO JOINT SESSION

Public Address Systems, by G. K. Thompson, Telephone Engineer, and J. P. Maxfield, of the American Telephone and Telegraph Co., New York, N. Y.

Use of Public Address Systems with Telephone Lines, by W. H. Martin, Dept., of Development and Research, American Telephone and Telegraph Co., New York, N. Y.

LECTURE

Observations on Electric Railway Practise, by William B. Potter, Chief Engineer, Railway and Traction Department, General Electric Company, Schenectady, N. Y.

THURSDAY MORNING, FEBRUARY 15

10:30 A. M.

TECHNICAL SESSION

Automatic Train Control Problems, by E. J. Blake, Electrical Engineer, Gould Coupler Co., Depew, N. Y.

Application and Economics of Automatic Railway Substations, by L. D. Bale, Engineer of Substations, Cleveland Railway Co., Cleveland, O.

Single-Phase Regeneration for Series Commutator Motors, by L. J. Hibbard, Railway Equipment Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

The Blondelion, by Vladimir Karapetoff, Professor of Electrical Engineering, Cornell University, Ithaca, N. Y.

Transient in Electrical Machinery, by W. V. Lyon, Asst. Professor of Electrical Engineering, Mass. Inst. of Tech., Cambridge, Mass.

1922 Developments in Auto Valve Lightning Arresters, by A. L. Atherton, Supply Engineering Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

THURSDAY AFTERNOON

2:30 P. M.

TECHNICAL SESSION

Telephone Transmission Over Long Cables, by A. B. Clark, Engineering Dept., American Telephone & Telegraph Co., New York, N. Y.

Machine Switching, by E. B. Craft, Asst. Chief Engineer, Western Electric Co., Inc., New York, N. Y., L. F. Morehouse, Equipment Engineer, American Telephone & Telegraph Co., New York, N. Y., and H. P. Charlesworth, American Telephone & Telegraph Co., New York, N. Y.

Wind Shielding Between Conductors, by F. J. Howe, Construction Engineer, Western Union Telegraph Co., New York, N. Y.

Electrical Oscillations on Lines and Cables, by Louis Cohen, Consulting Engineer, Washington, D. C.

Wave Antenna, by Harold H. Beverage, Chester W. Rice and Edward W. Kellogg, all of the General Electric Company, Schenectady, N. Y.

Theory of Electric Filter Circuits, by L. J. Peters, Electrical Laboratories, University of Wisconsin, Madison, Wis.

Diaphragmless Microphone, for Radio Broadcasting, by Philips Thomas, Research Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

THURSDAY EVENING

8:30 P. M.

Smoker under the auspices of the New York Section of the A. I. E. E., at which motion pictures will be exhibited, showing new method of speech transmission.

FRIDAY MORNING, FEBRUARY 16

10:30 A. M.

TECHNICAL SESSION

Dissymmetrical Electrical Networks, by A. E. Kennelly, Professor of Electrical Engineering, Harvard University and Mass. Inst. of Tech., Cambridge, Mass.

New Equation for Static Characteristics of Electrical Arcs, by W. B. Nottingham, Fellow of American-Scandanavian Foundation, Westfield, N. J.

Radiation from Transmission Lines, by Charles Manneback, Post-Graduate Student, Mass. Inst. of Tech., Cambridge, Mass.

Electromagnetic Forces; A Search for More Rational Fundamentals; A Proposed Revision of the Laws, by Carl Hering, Consulting Engineer, Philadelphia, Pa.

Physical Interpretation of Complex Angles and Their Functions, by A. Boyajian, Technical Engineer, General Electric Co., Pittsfield, Mass.

Permeability, by T. Spooner, Electrical Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

FRIDAY AFTERNOON

2:30 P. M.

TECHNICAL SESSION

Application and Limitation of Thermocouples for Measuring Temperature, by I. B. Smith, Research Dept., Leeds & Northrup Co., Philadelphia, Pa.

Measurement of Power in Polyphase Circuits, by C. Fortescue, Electrical Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Kilovolt-Ampere Demand Measurement, by H. C. Fryer, Supt. of Meters, Union Gas & Electric Co., Cincinnati, O.

Expansion of Oscillography by Portable Instrument, by J. W. Legg, Consulting Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Measurement of Transients, by F. Terman, Student at Leland Stanford University, Stanford, Calif.

Balance Methods in A-C. Measurement, by P. A. Borden, Hydro-Electric Power Commission Laboratories, Toronto, Ont.

FRIDAY EVENING

7:00 P. M.

Annual Dinner-Dance.

SATURDAY MORNING

Visits of Inspection.

Future Section Meetings

Boston.—January 9, 1923. Subject: "The Doble Method of Testing Insulators." Speaker: Mr. Frank C. Doble. This meeting will be in conjunction with the electrical students of Mass. Inst. of Tech.

February 13, 1923. This will be the annual dinner of the Affiliated Technical Societies of Boston. It will be followed by motion pictures and address by Mr. A. A. Northrop of Stone & Webster. The Subject shown will be "Caribou Hydroelectric Development."

Detroit-Ann Arbor.—January 12, 1923. Subject: "Experiences and Problems Encountered in the Electric Transportation System of a Large City." Speaker: Mr. H. M. Gould, Electrical Engineer, Dept. of Street Railway, Detroit.

February 9, 1923. Mr. D. H. Baer, Chief Electrician, Morgan & Wright Co. There will be a general description of the various kinds of electrical equipment required in a mammoth modern tire-making plant.

March 16, 1923. Associate Technical Society Meeting, sponsored by A. I. E. E.

New York.—January 19, 1923. There will be a meeting of the New York Section at which Dr. M. I. Pupin of Columbia University will speak. His subject will be "The Story of the Modern Physics." A cordial invitation is extended to all Institute members to attend. Meeting will be held in the Auditorium, Engineering Societies Bldg., 33 W. 39th St. at 8:00 p. m.

February 2, 1923. Mr. D. McFarlan Moore, Manager of Moore Light Dept., General Electric Company will describe the development of a new lamp never before demonstrated. The talk will be accompanied by actual demonstration and exhibit of the "Gaseous Conductor Lamp." The meeting will be in the Auditorium, Engineering Societies Bldg., 33 W. 39th St., at 8:00 p. m.

Pittsburgh.—January 9, 1923. Subject: "A-C. Substations for City, Industrial and General Distribution Work." Speaker: Mr. A. H. Kehoe, Supt. of Transmission and Distribution, United Electric Light & Power Co., New York.

Pittsfield.—January 18, 1923. Subject: "Power Development at Niagara." Speaker: Mr. J. L. Harper, Vice-President and Chief Engineer, Niagara Falls Power Co.

February 1, 1923. Annual Dinner. Speaker to be announced.

February 15, 1923. Speaker to be announced.

Schenectady.—January 5, 1923. Speaker: Mr. V. Karapetoff of Cornell University.

Toronto.—January 12, 1923. Subject: "Industrial Heating." Speaker not chosen.

January 26, 1923. Subject: "Large Power Distribution and Control." Speaker: Mr. P. E. Hart.

February 9, 1923. Subject: "Carrier Current." Speaker: Mr. Vennes.

February 23, 1923. Subject not chosen. Speaker not chosen.

Worcester.—January 18, 1923. Subject: "The New England Power System—Economic Aspects, Financial Structure, Organization." Speaker: Mr. S. C. Moore, General Manager, New England Power Co.

February 15, 1923. Subject: "Interior Wiring." Speaker: Prof. A. L. Cook, Head of Dept., Industrial Electrical Engineering, Pratt Inst.

Professor Pupin to give "The Story of the Modern Physics"

The Program Committee of the New York Section of the Institute announces that it has been extremely fortunate in securing Professor M. I. Pupin of Columbia University as the speaker for the New York Section meeting of January 19, 1923. There are few men, who are more familiar with the developments of modern physics than Prof. Pupin and when he undertakes to tell the story of this development it is an assurance of a most enjoyable evening to all who can arrange to hear him. Prof. Pupin is one of the few real orators in the engineers' ranks, and the talk he will give will appeal to specialist and layman alike. The Program Committee therefore urges every member of the Section to take advantage of this opportunity and extends a most cordial invitation to all Institute members of other Sections to attend if possible. The meeting will be held in the Auditorium Engineering Societies Building, 33 West 39th St., New York, at 8 p. m., Friday, January 19, 1923.

A. I. E. E. Directors Meeting

The regular bi-monthly meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Friday, December 8, 1922.

There were present: President Frank B. Jewett, New York; Vice-Presidents G. Faccioli, Pittsfield, R. F. Schuchardt., Chicago, Robert Sibley, San Francisco, W. I. Slichter, New York, N. W. Storer, Pittsburgh; Managers E. B. Craft, New York, A. G. Pierce, Pittsburgh, H. A. Pratt, Hoboken, H. B. Smith, Worcester; Treasurer George A. Hamilton, Elizabeth; Secretary F. L. Hutchinson, New York.

Chairman E. D. Adams of the Edison Medal Committee, present by invitation, announced that at a meeting of the committee held December 8 the 1922 Edison Medal had been awarded to Dr. Robert A. Millikan "for his experimental work in electrical science." Chairman Adams also reported upon the condition of the Edison Medal fund and suggested that consideration be given to certain questions of policy and procedure in connection with future awards, whereupon it was voted that the President be authorized to appoint a committee to confer with the Edison Medal Committee upon these and any other matters relating to the Edison Medal, and report to the Board at a later meeting.

Approval was given to the admission to membership in the American Engineering Standards Committee of the United States Department of Labor and the National Association of Manufacturers.

Approval by the Finance Committee of monthly bills amounting to $19,705.85 was ratified.

A resolution was adopted to the effect that the Secretary and the Treasurer, with the concurrence of the Finance Committee, be authorized to invest the $5000 which was appropriated for the Reserve Capital Fund of the Institute for the year 1921-1922, and that the Secretary and the Treasurer be empowered to execute any necessary documents in connection with this investment.

A list of members in arrears for dues for the year ending April 30, 1922, consisting of 8 Fellows, 29 Members, and 614 Associates, was presented; and the Secretary was authorized to remove from the membership list on December 31, 1922, the names of all those whose dues remain unpaid at that time and who have not indicated a desire to continue membership and requested an extension of time for payment of the dues.

Reports of meetings of the Board of Examiners held November 6 and December 4, 1922, were presented; and the actions taken at those meetings were approved. Upon the recommendation of the Board of Examiners the following action was taken upon pending applications: 803 Students were ordered enrolled; 78 applicants were elected to the grade of Associate; 6 applicants were elected to the grade of Member; 1 applicant was elected to the grade of Fellow; 8 applicants were transferred to the grade of Member; 1 applicant was transferred to the grade of Fellow.

Upon the recommendation of the Board of Examiners, the by-laws relating to the eligibility of students for enrolment in the Institute were amended. The two principal sections as revised are as follows:

Sec. 74. Any person registered as a full-time student in a university or technical school of recognized standing and pursuing a regular course of study in electrical engineering therein, may be enrolled as a Student of the American Institute of Electrical Engineers, as hereinafter provided. The designation of full-time students is intended to include those who devote either their entire time or the major part of their time to studies. The expression "school of recognized standing" is interpreted as applying to schools of college grade giving an electrical engineering course of not less than three years, and granting degrees.

Sec. 80. Students registered in electrical engineering subjects in schools other than those described above, and students registered in electrical engineering subjects in schools of recognized standing who do not devote the major part of their time thereto, while not qualified for Student enrolment in the Institute, may nevertheless subscribe for the regular monthly Journal at reduced rates by applying to the Secretary. The applications for such subscriptions must be accompanied by a certification from the instructor in charge of the electrical classes or department that the applicant is a student in electrical engineering subjects at that school. These subscriptions are for a term of one year only, but may be renewed twice upon similar certification.

Upon the recommendation of the Finance Committee, the by-law relating to the financial support of Sections was amended in accordance with the recommendations made at the conference of Section delegates at the Niagara Falls convention in June 1922. As revised, the by-law provides that the maximum appropriation for the work of each Section shall be the aggregate of two items, namely, (a) $175 for each Section, independently of the number of members in the Section, and (b) $1 for each Institute member within the territory of each Section at the beginning of the administrative year, August 1.

In accordance with the recommendation of the Sections and Finance Committees, the Board authorized the transfer of the members in Coshocton County, Ohio, from the Akron Section to the recently organized Columbus Section of the Institute, in conformance with the expressed desire of those members.

The following appointments were made: Mr. H. A. Lardner, reappointed as a representative of the Institute on the Board of Trustees, United Engineering Society, for a term of three years commencing January 1923; Mr. A. W. Kiddle, reappointed as a representative of the Institute on the Library Board, United Engineering Society, for a term of four years commencing January 1, 1923.

A request was presented for the approval of by-laws of the Standards Committee as adopted by the Committee on December 7; and the Board voted that a copy of the proposed by-laws of the Standards Committee be sent to each member of the Board with the minutes of this meeting and that action be deferred until the next meeting.

Upon the request of the Standards Committee, the Board authorized the Secretary to advise the American Engineering Standards Committee that the Institute deems it desirable that a conference on definitions, symbols and abbreviations in engineering work be called at an early date by the A. E. S. C.

Upon the recommendation of the Standards Committee, the Board accepted an invitation from the Bureau of Standards to be represented at a conference on radio standardization to be held in New York, January 12, 1923, and appointed Mr. L. T. Robinson as the representative of the Institute at this conference.

A report of the President of the U. S. National Committee of the International Commission on Illumination for the year 1921-1922 was presented, received and ordered filed.

President Jewett presented the question of the continuance

or discontinuance of the American Committee on Electrolysis, which had been taken up with him by Chairman Bion J. Arnold of the Committee in accordance with a resolution passed at a meeting of the Committee held October 2, 1922, at which time the question of disbanding the Committee was discussed. It was explained that the Electrolysis Committee was initiated by the A. I. E. E., which appointed three members and invited other organizations to appoint three members each, that the Committee issued a preliminary report in 1916, which was superseded by another report in 1921, and that it has a very active Research Subcommittee; also that after the second report was issued some of the members of the Committee thought it desirable to discontinue the Committee, while other members thought it should be continued with an active Research Subcommittee. The views of the Institute's three representatives on the Electrolysis Committee (Messrs. Bion J. Arnold, N. A. Carle, and Frank N. Waterman) had been requested and were all in favor of the continuance of the Committee. The value of the work of this committee was recognized by the Board; and the opinion was voiced that the Committee should continue in existence, and that in connection with the question of funds for the Research Subcommittee our representatives on the Committee be asked to prepare a statement or program which would give some idea of the financial support that would be involved. It was thereupon voted that the policy as outlined by Mr. Arnold be adopted by this Board—that the Committee be continued in a quiescent state and in the meantime carry on research work.

President Jewett presented a formal invitation from the Charles A. Coffin Foundation, recently established by the General Electric Company (See December 1922 JOURNAL of A. I. E. E.), for the Institute to appoint one member of a committee of three to advise and cooperate with the Foundation Committee which will award fellowships for research work in the fields of electricity, physics, and physical chemistry. The other two members of this advisory committee are representatives one each of the National Academy of Sciences and the Society for the Promotion of Engineering Education. President Jewett explained in detail the nature of the Foundation and the fellowships to be awarded; and the members of the Board expressed hearty approval of this action of the General Electric Company. It was voted that the invitation be accepted, that an expression of the appreciation of this Board of the policy adopted be conveyed to the General Electric Company, and that President Jewett be appointed the Institute's representative on this advisory committee.

Reference to other matters discussed may be found in this and future issues of the JOURNAL under suitable headings.

Award of Edison Medal for 1922

The Edison Medal for the year 1922 has been awarded by the Edison Medal Committee of the American Institute of Electrical Engineers to Dr. Robert A. Millikan of Pasadena, Cal., for "his experimental work in electrical science."

The Edison Medal was founded by the Edison Medal Association, composed of associates and friends of Mr. Thomas A. Edison, and is awarded annually by a committee consisting of twenty-four members of the American Institute of Electrical Engineers for "meritorious achievement in electrical science, electrical engineering, or the electrical arts."

Dr. Millikan was born in Morrison, Ill., in 1868, is a graduate of Oberlin, Class of 1891 and was granted a Ph. D. from Columbia in 1895. He also holds degrees from Berlin and Gottingen, Northwestern, Pennsylvania and Amherst. He took up the teaching of physics at Oberlin in 1891, and from there went to the University of Chicago where he became Assistant Professor of Physics in 1901, Associate Professor in 1907 and Professor in 1910. In 1921 he became Director of the Norman Bridge Laboratory of Physics at the California Institute of Technology where he is also Chairman of the Administrative Council.

Probably the best known and most noteworthy of Millikan's works are his so-called "oil-drop" experiments, undertaken for the purpose of making precise measurements of the fundamental electrical quantity. These experiments proved conclusively that all electrons are alike and the results obtained have been of inestimable value in the calculations of physical constants.

Second only to the oil-drop experiments is his work on photo-electric effect and his measurement of the "h" constant, which has to do with growth and decay of photo-electric phenomena. This work is recognized as the best experimental check on some of the Einstein hypotheses. His more recent work has tended toward a definite bridging of the gap between light and X-ray phenomena.

Although Millikan's claim to recognition rests particularly on his experimental researches, his work during the war and in the formation of the National Research Council, on which he served as executive head, is particularly noteworthy. To Dr. Millikan probably above all others is due the credit for whatever good resulted from the activities of America's scientists, he contributed not only from his own great store of knowledge but was largely the driving force which directed the activity of others, including the Government Bureaus, and stimulated individuals to an almost superhuman activity.

Dr. Millikan is the author of numerous books on Physics and has contributed largely to the technical press on the same subject. He is a member of the National Academy of Sciences, American Philosophical Society, American Physical Society, the American Institute of Electrical Engineers; also the Cosmos, Quadrangle, University and Valley Hunt Clubs.

North Eastern Geographical District Executive Committee

The Executive Committee of the Institute's Geographical District No. 1, which comprises New England and New York State (exclusive of New York City), held an interesting and profitable meeting at the Hotel Wendell, Pittsfield, on the afternoon of Tuesday, December 5.

The executive committee of each Geographical District is composed of the vice-president representing the district and the chairmen and secretaries of all the Sections within the district. The purpose of these committees as defined in the by-laws of the Institute, is to facilitate cooperation between the Sections within the district.

This meeting, which was arranged for, and presided over by, Vice-President G. Faccioli, was attended by representatives of seven Sections, also by national secretary Hutchinson and Mr. E. E. F. Creighton, Chairman of the national Meetings and Papers Committee. The Section representatives present were:

Boston: E. L. Moreland, W. R. McCann. Connecticut: E. H. Everit, Wm. A. Moore. Lynn: J. W. West, W. M. Howe. Pittsfield: W. P. White, A. C. Stevens, E. D. Eby, J. R. Rue, I. H. Sclater, N. F. Hanley. Schenectady: C. M. Davis. Springfield: W. A. Dick, J. F. Murray, J. P. McKearn. Worcester: F. J. Adams, H. O. Tilton.

There was an animated discussion, in which all present participated, relative to the various activities of the Institute, and particularly of Sections. The desirability of the various Sections within the district exchanging their proposed programs as early in the season as convenient was emphasized; and it was voted that in each Section the local program committee should arrange for the first two meetings of the following administration, inasmuch as in most Sections the administrative year begins on August 1 and, therefore, committees appointed after the beginning of the administrative year find it difficult to arrange satisfactory meetings for the early fall.

In order to avoid confusion with the national Meetings and Papers Committee, it was agreed to recommend to each local executive committee that the local meetings committee be designated the "Program Committee."

It was further agreed that in appointing committees it is desirable that some members be reappointed, in order to bring about more readily, continuity of policies and plans. (This is the practise invariably followed by the Institute's presidents in appointing national committees.)

Chairman Faccioli referred to the $100 prize offered by the national body for the first paper presented by any member at any meeting of the Institute or of a Section. Several members reported that papers were being prepared for this competition by members of their Sections. Secretary Hutchinson reported that two papers have already been received at Institute headquarters in competition for this prize for the year 1922. Each Section was urged to bring forward at least one candidate for this prize.

In addition to the prize offered by the national body, Mr. Faccioli stated that he had given a great deal of thought to the award of a prize for the best paper presented by a member at any meeting held in Geographical District No. 1 during the year; and a general discussion resulted regarding the desirability of such a prize, method of financing, conditions of award, etc. It was generally agreed that such a prize would probably result in influencing a number of young engineers to prepare papers in competition; and the sentiment was that the prize should consist of a small amount of money, together with a suitable diploma. It was definitely voted to recommend to the executive committee of each Section in the district that they make a small contribution toward such a regional prize, the contest to be conducted and the prize to be awarded under the direction of a committee to be appointed by the chairman of the Executive Committee of the district.

During the discussion it was agreed that in arranging for meetings a wide variety of topics should be covered during the year, for the purpose of interesting different groups of members; also that the educational function of the Institute in developing the latent abilities of its members, should be kept constantly in mind; and, therefore, that the programs of the majority of the meetings of Sections should consist principally of the presentation and discussion of topics in the electrical engineering field by local members, with, however, a limited number of visiting speakers during each year.

The scope of the contents of the Institute JOURNAL was also discussed. It was the consensus of opinion that the highly theoretical papers which heretofore have comprised the major portion of the contents of the JOURNAL, constitute the history and foundation of electrical engineering. Nevertheless, it was hoped that additional engineering articles of a different nature, describing for example new machines and engineering practises, also those discussing executive and operating problems, would be included; and attention was called to the fact that the Board of Directors of the Institute has already approved the policy of including in the JOURNAL material of the latter character.

It was agreed by all present that meetings of the Geographical Executive Committee are exceedingly valuable in bringing about coordination of the work of the Sections; and it was voted that another meeting of this committee be held in March 1923.

Upon the adjournment of the meeting the visiting members were the guests of the Pittsfield Section at an informal dinner, after which nearly all present attended an interesting meeting of the Pittsfield Section, as reported elsewhere in the JOURNAL.

Governor Morrow to Speak on "Operation of the Panama Canal"

The N. Y. Section of the American Society of Civil Engineers announces a meeting to be held at 7:45 p. m. on January 10, 1923, Auditorium, Engineering Societies Building, 33 West 39th St., New York, N. Y., at which General Jay J. Morrow, Governor of the Canal Zone will give an address on "Operation of the Panama Canal." This address will be illustrated both by moving picture films and by lantern slides and will be followed by an address by a prominent representative of the Shipping Industry, after which the subject will be open to discussion. A most cordial invitation is extended by the Civil Engineers to the N. Y. Section of the A. I. E. E. and other Institute members to attend.

Proposed National Engineering Museum

The Joint Committee on a National Museum of Engineering and Industry appointed by the four Founder Engineering Societies is constituted as follows: American Institute of Electrical Engineers, Edward D. Adams, and Charles L. Clark; American Institute of Mining and Metallurgical Engineers, Frederic A. Delano and Dr. Geo. F. Kunz; American Society of Civil Engineers, Clemence Herschel and Nelson P. Lewis; American Society of Mechanical Engineers, Reginald P. Bolton and Holbrook F. J. Porter. Mr. Porter will act as chairman, with headquarters in the Enigneering Societies Building, 29 W. 39th St., New York City.

The committee has already visited the Smithsonian Institution at Washington, D. C. and is cooperating with it in formulating a place for a great National Museum of Engineering and Industry similar to the Science Museum at South Kensington, London, England, Conservatoire des Arts et Metiers at Paris, France, and Deutsches Museum at Munich, Germany, but suited to the needs of this country which has a greater area than those mentioned, by having a central institution and branches in different sections, of a character and scope to serve their respective requirements and with proper exchange facilities.

The committee invites the interest and cooperation of the engineers of the country in preserving the records of their work for eventual deposit in the National Museum and solicits correspondence regarding their ideas as to the character, scope and location of the central institution and the sectional branches.

Annual Meeting of the American Society of Civil Engineers

The Annual Meeting of the American Society of Civil Engineers will be held in New York City on January 17, 18, and 19, 1923 and will be largely devoted to discussions of Education, Research and City Planning. On the evening of January 18, Julius H. Barnes, President, Chamber of Commerce of the United States, will deliver an address on "Transportation Keyed to Production."

During the morning session of January 17, prizes and medals will be awarded to members for excellence in papers published by the Society during the past year and Honorary Membership will be conferred upon the following distinguished engineers Leon-Jean Chagnaud, Paris; Sir Maurice Fitzmaurice, London; Clemens Herschel, New York City; John F. Stevens, New York City; and William Cawthorne Unwin of London. Another feature of the Meeting will be an all day excursion on Thursday, January 19, to the plant of the Bethlehem Steel Company at Bethlehem, Pa.

The subject of Engineering Education will be discussed during the afternoon of January 17 in a Joint Session with the Society for the Promotion of Engineering Education at which Charles F. Scott, President of the Society for the Promotion of Engineering Education, will speak on "The New Project of the Society for the Promotion of Engineering Education." Other speakers scheduled are William G. Raymond, Dean, College of Applied Science, State University of Iowa who will discuss "The Outlook of the Engineering Colleges of the Middle West." Magnus W. Alexander, Managing Director, National Industrial Conference Board will present a paper on "The Objective in Engineering Education" and John L. Harrington, President, American Society of Mechanical Engineers, will speak on "Cooperation of National Engineering Societies in Engineering Education."

Engineering Research will be the topic of discussion at the morning session of January 19, at which the speakers scheduled are Arthur N. Talbot, Professor of Municipal and Sanitary

Engineering, and in charge of Theoretical and Applied Mechanics, University of Illinois, who will present a paper on "The Research Activities of the American Society of Civil Engineers." Alfred D. Flinn, Director, Engineering Foundation; Chairman, Division of Engineering, National Research Council, New York City, will outline the Work of Engineering Foundation and of the Engineering Division of National Research Council. George K. Burgess, Chief of the Division of Metallurgy, U. S. Bureau of Standards, Washington, D. C., will discuss "The Study of Steels for Engineering Structures," and Otto B. Blackwell, Transmission Development Engineer, American Telephone and Telegraph Company, New York City, will speak on "Radio and Research."

The afternoon of January 19 will be devoted to a discussion of City Planning, Nelson P. Lewis, Consulting Engineer; Director, Physical Survey Plan of New York, Russell Sage Foundation, New York City, will discuss "Regional Planning." Linn White, Chief Engineer, South Park Commission, Chicago, Ill., will speak on "Parks and Parkways." Morris Knowles, Chairman, Pittsburgh City Planning Commission, will present a paper on "Zoning," and George H. Norton, City Engineer; Chairman, City Planning Commission, Buffalo, N. Y., will discuss "City Planning and the Engineer."

International Electrotechnical Commission Advisory Committees Meet in Geneva

Meetings of the I. E. C. Advisory Committees on Rating, Graphical Symbols, Standard Pressures and Regulations for Overhead Transmission, as well as Screw lamp caps and holders, were held in Geneva, commencing Monday, November 20th, and continuing until November 26th, 1922.

Mr. E. Huber, President of the Swiss Committee on behalf of his colleagues welcomed the delegates from the various Nations.

The question of the rating of electrical machinery occupied the major portion of the time, being the most important subject and the principal reason for the convening of the meetings. There were 58 delegates present from 11 nations. Dr. Mailloux, the President, and Col. R. E. Crompton, the Honorary Secretary, of the Commission, were also present. In addition to President Mailloux the following were present from the United States: Messrs. C. L. Collens, 2nd, M. D. Cooper, S. E. Doane, George Harries, H. M. Hobart, M. K. MacGrath, F. V. Magalhaes, C. H. Sharp (Secretary U. S. Committee), C. E. Skinner, Schuyler S. Wheeler.

At the opening session, Dr. Mailloux on behalf of the I. E. C. thanked Mr. Huber and the Swiss Committee for the excellent arrangements made for the convenience and comfort of the delegates. At the meeting of the Advisory Committees held in Brussels in 1920 he had thought it would have been possible to have had further meetings at a much earlier date but various circumstances had prevented this.

The preparation for the present meetings had necessitated a great deal of consultation between the Central Office and the various national Committees, and the General Secretary besides having gone to Berlin, had done everything he could in consultation with the national Committees to arrive at an understanding as complete as possible before actually convening the meetings.

A point of particular interest was the fact that the Swiss Committee in offering the Commission their hospitality had prepared the way for more complete international accord, and he felt sure he was expressing the views of all present when he hoped that the visit of Dr. Strecker, one of the earliest workers in the I. E. C., and his colleagues, as the guests of the Swiss Committee, would be the first step in renewed cooperation with the German electrical industry.

The meetings were held in close proximity to the great League of Nations and in a hall of immense historical interest, the "Alabama" Room, where the Alabama claims of the United States against England were settled. The I. E. C. itself was the league of nations for the Electrical Industry of the world, and he hoped that at these meetings results might be attained which would give everybody the fullest satisfaction.

Mr. E. Huber was elected to preside over the technical sessions of the Rating Committee, and arrangements were made for meetings of the other Advisory Committees to be held during the week.

The main object of the meetings of the Advisory Committee on Rating which was convened principally at the request of the British National Committee, was to consider the difficulties which have arisen in the attempt to introduce into practise the method recommended by the I. E. C. of rating electrical machinery on the maximum continuous load.

The British Delegation stated that it had been found possible to adopt the I. E. C. 50 deg. rating without overload for certain classes of machine, but for the ordinary type of industrial motor and generator the established British practise had for many years past been to rate these machines on a 40 deg. temperature rise with an overload of 25 per cent for two hours. The British Committee had found itself in a difficult position in its efforts to be loyal to its industry and to the I. E. C. as well; and this was the reason why it appealed to the I. E. C. for assistance in finding a solution of the problem confronting it. The British were most anxious that an overload rating of this nature should be recognized by the I. E. C. and were moreover desirous that temperature rise alone should be specified and that the rating be based on the temperature rise at full load and not on the overload. In Great Britain it should be noted that the cooling air temperature does not exceed 30 deg. cent. and indeed is more nearly 20 deg. cent., and this overload therefore does not produce maximum temperatures in excess of those laid down by the I. E. C.

The British also felt that while established British practise in regard to industrial motors gives a more substantial machine than the 50 deg. rating of the I. E. C. without overload, unless the I. E. C. agreed to adopt an overload rating for this class of machine, the rating the British desired to standardize in their own country would not actually be in accordance with the I. E. C. rules although it might be within them.

Some misunderstanding arose in regard to the question of the temperatures produced on the overload, as an overload rating, if adopted by the I. E. C. would have to be applicable to all countries where the ambient temperature does not exceed 40 deg. cent.

The British Delegation while emphasizing the fact that the ultimate temperature limits of the I. E. C. had been based on laboratory experiments carried out many years ago and experience with the use of the modern materials and methods of measurement might justify a review of the I. E. C. maximum temperature limits, yet at present they were most desirous of putting forward only such proposals as would be entirely within the I. E. C. limit..

Some discussion then took place as to the necessity of the I. E. C. introducing overloads seeing that any National Committee is perfectly at liberty to specify overloads in their national rules so long as this does not involve temperatures beyond the I. E. C. figures. In view, however, of the commercial importance attached to this question by the British Committee, the other delegations, desiring to give satisfaction to the British, after further discussion agreed to consider the question of recommending the introduction within the I. E. C. limits of a nominal rating with an overload as an international standard.

In deference therefore to the British views, the Advisory Committee, with the help especially of M. Boucherot (France) and Signor Semenza (Italy) endeavored to find a solution satisfactory to their British colleagues.

The American delegates had not come with any preconceived ideas or definite proposals but were at the same time inclined

to favor the British suggestion although they pointed out that there was a tendency in the United States toward a 40 deg. single rating without overload which would imply a liberally designed machine capable of carrying both the mechanical and electrical overloads that such machines have to meet in ordinary service. They urged most strongly that one rating only should be adopted.

After long consideration a generally acceptable proposal embodying the wishes of the British delegates was agreed to for submission to the National Committees to the effect that overload ratings within the I. E. C. maximum continuous rating be recognized and that, for general industrial machines (the class to be defined later) where overloads have to be provided, a machine having a 40 deg. cent. temperature rise and capable of carrying 25 per cent overload for two hours applied at the end of the full-load run be recommended, the overload only to be applied under such conditions of air temperature as will not cause the limits of maximum temperature laid down by the I. E. C. to be exceeded. It will be remembered that the main object of the international rating of electrical machinery is to establish an equitable basis of comparison of tenders and much discussion took place as to the method of indicating the relation between the proposed British nominal rating and the I. E. C. single rating. To carry this into effect Signor Semenza suggested, and it was ultimately agreed to recommend that the rating plate of the machine indicate in addition to the other information the output under the ordinary I. E. C. continuous rating (50 deg. cent. rise).

With this decision the meetings of the Advisory Committee were adjourned and the British delegates expressed their thanks and appreciation of the manner in which their proposals had been received. They had fulfilled their obligation to consult the Advisory Committee before introducing into their National Rules recommendations at variance with those of the I. E. C. and in view of the agreement now arrived at they felt, and the members agreed, that they would be at liberty to proceed with the urgently required revision of their National Rules introducing into the new British Rules a lower temperature rise and an overload rating conforming as to ultimate temperatures with the I. E. C. limits and indicating that the same time on the rating plate the relation between their 40 deg. rating with overload and the I. E. C. 50 deg. single rating.

The German representatives at the close of the meeting expressed their appreciation of the manner in which they had been received and said their desire was to resuscitate the German National Committee and its work, and, in so far as is possible to bring the German rules entirely into harmony with the Rules of the I. E. C.

A meeting of the Advisory Committee on Graphical Symbols was held with Dr. Wyssling (Switzerland) in the Chair.

The proposals put forward at Brussels in 1920 were carefully looked through and additional symbols were added. In the discussion the delegates had before them the graphical symbols issued by the B. E. S. A. (B. S. S. No. 108) and those of the Italian and Swedish and Swiss Committees.

A meeting in regard to Standard Pressures and Regulations for overhead transmission was also held, and in this case Dr. Mailloux took the chair.

With regard to the standard pressures recommended to the National Committees by the Advisory Committee at Brussels, the various delegates gave their views. The recommendations made at Brussels including the proposal to adopt 45,000 (declared pressure) as the intermediate pressure between 30,000 and 60,000 were confirmed.

The French suggestion that 120,000, 150,000 and 220,000 volts should be the next stages was briefly discussed, and referred to the National Committees but without a specific recommendation.

A most interesting point was brought forward by Mr. Doane (U. S. A.) regarding the low pressures for electric lighting, stating that a pressure in the neighborhood of 110 or 115 volts was becoming a necessity from experience in the economic production of light.

The detailed work in regard to overhead transmission was not sufficiently advanced for more than a general exchange of views but it was agreed to ask the Belgian Committee, which had taken a most prominent part in the question of regulations for overload transmission, to bring forward for consideration a skeleton set of rules which might be adopted as a guide for all countries.

A meeting of the Advisory Committee on Screw lamps, caps and holders was also held and was presided over by Dr. Mailloux. This is the first occasion on which the manufacturers of lampholders in the different nations have come together under the same roof. The ground had been fully prepared by M. Zetter (Paris) and Mr. S. W. Attwell (Great Britain) and also by the Americans and as a result of an exhaustive review of the situation, the proposal of Mr. Doane (United States) that the lamp holder should first be standardized rather than the lamp cap, was agreed to and proposals in full detail are to be drawn up in consultation with the experts in the various works manufacturing the lampholders and to be put forward at an early date.

The difficulties in the way of accomplishing this much desired object do not seem so insuperable as had previously appeared, and as the meeting included representatives from Holland, Germany, United States, Sweden and Great Britain, there is every reason to look forward to an early solution of this problem of such importance to the progress of the electric lighting industry.

The delegates were entertained at a reception at the Opera House by the Town Council, and at a banquet given by the Swiss Committee. They also paid interesting visits to the League of Nations where they were received by Sir Eric Drummond, K. C. B., the Secretary-General, and where the aims and objects of the League were fully explained. A visit was also paid to the works of Secheron & Co. where large electric locomotives were in progress of manufacture.

Special arrangements were made for the delegates, by electric trams and automobile, to visit the water power works erected on the Rhone at Chauzy-Pougny.

It was agreed on all hands that in spite of the difficulties surrounding the subject of the rating of electrical machinery, the meetings of these Advisory Committees have proved not only successful but of the highest importance and once more have demonstrated the immense usefulness of the I. E. C. as a means of bringing engineers of the world together and of promoting the unity of interest which, in spite of the divergencies due to national practise, exist to a marked degree in the electrical industry.

The I. E. C. in common with organizations of a similar nature, is however sadly hampered from want of funds, but it is hoped that as the wheels of industry begin once again to revolve this very serious difficulty will, at any rate to some extent, be overcome through the increased interest being taken in the work by the great industrial organizations in the different countries, which are well able to assist when once they realize the utility of the Commission to the progress of international commerce.

POWER COMMISSION STARTS NEW POLICIES OF ADMINISTRATION OF WATER POWER ACT

At its meeting on November 20, the Federal Power Commission inaugurated two new policies of administration and questions were raised in connection with several cases involving interpretation of the waterpower act.

In the future the Commission will follow a policy to revoke preliminary permits in cases where specified investigations are not completed within a reasonable time. This policy so far has affected two preliminary permits after the applicants had been given due notification of the Commission's intention.

The Commission has always insisted that valuation work be determined before a license was granted. This was waived in the case of an application from a company in San Francisco and the license was approved. The question of valuation in this case was left for future consideration and the Commission agreed to accept the valuation fixed by the State Railroad Commission of California.

The first license was granted to a municipality when the Commission interpreted the waterpower act so as to grant a license for the two constructed plants belonging to the City of Los Angeles. In the future the Commission indicated that the burden of proof will rest with municipalities who will have to show that their projects are operated without profit.

A question also was raised as to proper interpretation of the act provided that there shall be no charge for license for projects developing less than 100 h. p., the point raised being whether administrative charges or all charges are to be cancelled.

A number of projects were disposed of in the regular routine business of the Commission.

American Engineering Standards Committee

REVIEW OF INDUSTRIAL STANDARDIZATION DURING THE YEAR 1922

By Albert W. Whitney

Chairman, American Engineering Standards Committee

The year 1922 has seen greater activity in industrial standardization than any other year in the history of American industry. Notable progress was made during the year in standardization of raw materials, of manufacturing processes, and of finished products by individual firms, by industrial and technical associations and by bodies that are working on national and international lines.

One of the most far-reaching accomplishments of the year was the organization, on a working basis, of the Federal Specifications Board which develops and approves the specifications under which all government purchases are made, and the development of a plan of cooperation between this Board and the American Engineering Standards Committee; the carrying out of this plan should go far toward eliminating the difference between specifications for government purchases and specifications for ordinary commercial supplies and should thereby result in the saving of millions of dollars both for the government and for industry.

The organization of Secretary Hoover's Division of Simplified Practise and its entrance into industrial field has had a highly stimulating effect on the industrial standardization movement and has helped in particular to press home to the business man that standardization is one of the main approaches to efficiency and the elimination of waste.

Great advances have been made by industry itself on the more technical side. More than 120 standardization undertakings now have an official status before the American Engineering Standards Committee, 43 of them having been initiated within the last year; this is an increase of more than 50 per cent. Of the 28 industrial standards developed and approved by the American Engineering Standards Committee since its organization in 1918, thirteen were approved within the past year. The efforts to develop national safety codes, which have been under way for a number of years, began for the first time to bear fruit. Six important safety codes, pointing the way to the elimination of the most serious classes of industrial accidents, were approved during the year.

Another outstanding accomplishment in the industrial standardization work of this year was the development of the "standardization-by-conference" idea, in which all of the interests involved in the subject, including producers, consumers, and representatives of the public and government, participate in deciding; first, whether standardization is to be undertaken, second, what shall be its scope and third, what shall be its relation to other standardization work.

The year 1922 saw also the development of an increased interest in industrial standardization and an increased appreciation of its effect on production efficiency, distribution of costs, and consumer demand, on the part of such important commercial bodies as the International Chamber of Commerce, the Chamber of Commerce of the United States, and the New York State Chamber of Commerce. It is highly desirable that such cooperation should be maintained if American industry is to be given the commercial advantages which will correspond to those that are being developed through standardization in Germany and England and other foreign countries.

The last year saw important developments in international standardization. There are now national standardization bodies in 15 foreign countries and a report recently received by the American Engineering Standards Committee indicates that plans are under way for the development of such work in each of the South American republics. The most recent of the national bodies is the Australian Engineering Standards Association, which held its first meeting on November 3.

One of the most encouraging developments of the year has been the growth of interest in standardization and simplification among the many trade associations of America. These associations, representing large groups of producers and consumers, have extremely favorable opportunities both for developing industrial standards and for putting them into effect.

It is universally recognized that standardization is a legitimate and constructive activity of trade associations. The clarification of the legal aspects of the question by the publication in the early part of the year of the correspondence between the Attorney-General and Secretary Hoover has done much to foster and extend standardization activity among trade associations.

SYSTEM FOR NUMBERING OF STEELS TO BE DEVELOPED UNDER PROCEDURE OF A. E. S. C.

A system of designating kinds or qualities of steels by code numbers, each of which would represent a definite specification, will be developed as a result of the decision of a conference of the principal producers and users of steel held at Washington, D. C., December 6, at the call of the American Engineering Standards Committee. The conference recommended that this code be developed under the procedure of the A. E. S. C. and suggested to that organization the appointment of the Society of Automotive Engineers and the American Society for Testing Materials as joint sponsors for the code.

The agreement to go ahead with this project was arrived at after a spirited discussion concerning the necessity for and practicability of a numbering system. Strong opinions in favor of the designation of steels by number were voiced by heavy buying interests, such as the U. S. Navy Department, the Electrical Manufacturers' Council, the Society of Naval Architects and Marine Engineers, the U. S. War Department and the Federal Specifications Board.

The arguments used against the numbering of tool steels, Admiral Cone declared, were identical with the arguments used

25 years ago against the writing of specifications for steel of any kind. The conference voted that it is desirable to have a uniform numbering system, based on specifications, for forging steels, casting steels, structural steels including plates, tool steels, and other steels.

The conference was opened by a résumé of present American practise in designing steels, by Dr. G. K. Burgess, Chief of the Division of Metallurgy of the U. S. Bureau of Standards, and a résumé of European practise by L. H. Fry, representing the American Society for Testing Materials. Mr. Fry said that Switzerland and Germany have already taken definite steps toward a numbering system. The method proposed in Switzerland provides a system of symbols intended to be universal and definite, and capable of expansion to suit new requirements. In France a method is offered by which steels will be numbered with relation to a definite specification for the type, augmented by a letter indicating the method of manufacture, and a number showing the minimum tensile strength. In Great Britain a numbering system is employed for aircraft steels, and a tendency is appearing to develop symbols for automobile steels. Some limited symbolization is used in Holland also.

POWER PRESS CODE AND HEAD AND EYE SAFETY CODE

Approved by the A. E. S. C.

The frequency of two of the most serious and most common types of industrial accidents should be greatly reduced through the application of two safety codes which have just been approved by the American Engineering Standards Committee. The Safety Code for Power Presses, Foot and Hand Presses, which has been approved as "Tentative American Standard," is the first national safety code on this subject to be prepared in America. The Safety Code for the Protection of Heads and Eyes of Industrial Workers, which has now received the A. E. S. C. approval as "American Standard" had been approved by the Committee some time ago as "Recommended American Practise."

While no national statistics of power press accidents are available, it is the general opinion of safety engineers that the high speed punch or forming press—of which there are tens of thousands in use—is one of the most dangerous machines in industry and that hundreds, if not thousands, of fingers, hands and arms are cut off or mutilated on power press accidents each year. Heretofore each industry has tried to work out its own methods of preventing power press accidents and in many cases individual plants have attempted to solve this problem out of their own experience without reference to what has been accomplished in other plants.

The power press safety code sponsored by the National Safety Council, was formulated by a committee of twenty-one men. This code consists of two parts,—the first part describing standard requirements and the second consisting of a discussion of press hazards and protective methods and devices. The section on standard requirements covers such subjects as the location and installation of presses, feeding and removing material, making and setting of dies, and operating rules. The second part of the book discusses general methods of protection, automatic and semi-automatic feeding devices, enclosing guards, hand tools, methods of removing materials, methods of forcibly removing hands, two-hand operating attachments, gage guards, and non-repeat and treadle disconnecting attachments.

A statement from the National Committee for the Prevention of Blindness calls attention to Dr. Earl B. Fowler's estimate that there are in the United States approximately 15,000 persons who have been blinded by industrial accidents and that this is almost 15 per cent of the blind population of the country. In one state alone, Pennsylvania, 652 industrial workers lost one eye each and 18 lost both eyes in accidents during a single year.

Because of this serious situation the U. S. Bureau of Standards with the cooperation of the War and Navy Departments began in 1918 the preparation of a head and eye safety code. Several years ago this code was submitted for the approval of the American Engineering Standards Committee and it has since then been the subject of investigation, criticism, and revision by a sectional committee made up of representatives of industry, insurance companies, employees, the manufacturers of protective equipment, safety societies and several state and federal government departments. The existence of this code makes it possible for the various state industrial commissions and municipal factory departments to put into force a set of regulations which represents the consensus of opinion as to the best method of preventing industrial eye accidents.

AUTOMOBILE HEADLIGHT TESTING SPECIFICATIONS APPROVED BY AMERICAN ENGINEERING STANDARDS COMMITTEE

One of the tribulations of the touring motorist—the hopeless attempt to comply with the automobile headlighting regulations of all the states through which he passes on his trip across the continent—will be removed as soon as the various state motor vehicle departments have all adopted the Specifications of Laboratory Tests for Approval of Electric Headlighting Devices for Motor Vechicles which has just been approved by the American Engineering Standards Committee.

The approval of one set of specifications for such a test by the American Engineering Standards Committee, which is the national clearing house for standardization information and which provides the machinery for developing standards on a national scale, will place before the motor vehicle departments of all the states what represents the consensus of opinion concerning the most effective and most desirable method of testing automobile headlights. Even before these specifications had been formally approved by the A. E. S. C. nine of the states indicated that they would adopt the specifications; in three states they are already in effect.

These specifications were submitted to the A. E. S. C. by the Illuminating Engineering Society. This organization and the Society of Automotive Engineers have been appointed joint sponsors for any revision and further development of the code which may be necessary. Approval of the specifications was recommended to the American Engineering Standards Committee by a Special Committee which had been appointed to investigate their practicability and acceptability. This Committee, of which David Van Schaack, vice president of the National Safety Council, was Chairman, was made up of representatives of the automobile manufacturing industry, automobile accessory manufacturers, the officials of motor vehicle regulatory bodies, insurance companies, safety organizations, technical societies, and of the U. S. Bureau of Standards.

ENGINEERING FOUNDATION

INVESTIGATION OF ARCH DAMS BY ENGINEERING FOUNDATION

After careful preliminary consideration, the Engineering Foundation has inaugurated an investigation of arch dams and has appointed the following advisory committee: F. E. Weymouth, Chief Engineer, U. S. Reclamation Service, Denver, Colorado; H. F. McClure, State Engineer, Sacramento, California, (alternate): Paul Bailey, Deputy Chief of Public Works, representing the State of California; M. M. O'Shaughnessy, City Engineer, San Francisco (alternate: R. P. McIntosh, designing engineer), representing San Francisco; H. Hobart Porter, member of Engineering Foundation, New York, (alternate: Wynn Meredith, of Sanderson & Porter, San Francisco); Silas H. Woodard, member of Engineering Foundation, New York; Prof. C. Derleth, Jr., University of California, Be rkeley

California; H. Hawgood, consulting engineer, Los Angeles; D. C. Henny, consulting engineer, Portland, Oregon; Fred A. Noetzli, Chief Engineer, Bissell & Sinnicks, San Francisco, Secretary. All members of the committee are members of American Society of Civil Engineers. A Chairman is to be chosen at a meeting to be held in December or January.

The purposes of the investigation are, first, to collect all possible information regarding design, construction, history and behavior of existing arch dams, and, second, to study by observation of existing dams or those to be built in the near future, or of test dams, the movements under changes of load, temperature and other conditions. From all these studies it is hoped that there may be evolved a more rational and generally acceptable method for the design of arch dams than those now in use. Among the objects sought is economy combined with that degree of security which is demanded in each case.

AMERICAN ENGINEERING COUNCIL

ENGINEERING LECTURES AT YALE UNIVERSITY

Lectures by prominent engineers are being made part of the program of development of the engineering courses in the Sheffield Scientific School of Yale University along broader university cultural lines. These lectures will deal with the engineering profession as a whole—with its history, opportunities and obligations, with its attitude toward public and private needs, its notable achievements, and kindred topics.

Special lectures are being chosen both for their knowledge of engineering and for their experience in dealing with public problems. The first lecturer was John Hays Hammond. The second will be L. W. Wallace, executive secretary of the Federated American Engineering Societies, and a former member of the faculty of Purdue University. Mr. Wallace, who was vice-chairman of the Hoover Committee on Elimination of Waste in Industry, and who is president of the Eye Sight Conservation Council of America, will speak at Yale on December 12.

Mr. Wallace's subject will be "The Engineer in Industry." Among other things he will discuss the report of the Committee on Work-Periods in Continuous Industry of the Federated American Engineering Societies, which found that the twelve-hour day in industry was economically unnecessary. President Harding has characterized this report as representing his "social viewpoint."

PRINCE GELASIO GAETANI HONORED BY ENGINEERS

American engineers are planning a big reception for Prince Gelasio Gaetani, Italian ambassador to Washington, now on his way to this country. A dinner, at which engineers from all parts of the country will be present, will be given in honor of the new diplomat, himself an engineer, by the American Engineering Council of the Federated American Engineering Societies in Washington on the evening of January 12, it was announced by L. W. Wallace, executive secretary of the Federation.

INTERNATIONAL ENGINEERING CONGRESS BOARD OF MANAGERS TO HAVE MEETING

The Board of Managers to have charge of this Congress has been called to meet at the Engineers Club of Philadelphia on Tuesday, December 5. This Congress is to be held in conjunction with the Sesqui Centennial celebration in Philadelphia in 1926.

The Board of Managers is composed of engineers appointed by the various organizations. Federated American Engineering Societies has appointed J. Parke Channing and L. P. Alford as its representatives. Other appointments have been made as follows:

George S. Webster, Richard L. Humphrey, representing A. S. C. E.; J. Viponi Davies, Charles F. Rand, representing A. I. M. & M. E.; James Hartness, D. Robert Yarnall, representing A. S. M. E.; Arthur E. Kennelly, Charles E. Skinner, representing A. I. E. E.; W. C. L. Eglin, Charles E. Billin, representing Engineers Club of Philadelphia.

As a result of this meeting it is contemplated that plans will be set in motion for one of the most important engineering congresses ever held in this country.

PLANS DEVELOPING FOR ANNUAL MEETING OF THE AMERICAN ENGINEERING COUNCIL

The annual meeting of the American Engineering Council to be held in Washington on Thursday and Friday, January 11 and 12 will be called to order in the Assembly Room of the Cosmos Club.

This meeting will be preceded by a meeting of the Executive Board and after the adjournment of the Council on Friday the newly elected Executive Board will meet.

Many important questions are awaiting decisions by both the Council and the Executive Board. On Thursday evening the Council will go to the Chevy Chase Club for its annual dinner. The new Italian Ambassador, Galasio Gaetani, who is both a civil and a mining engineer, has been invited to address the Council, together with other prominent speakers.

NATIONAL RESEARCH COUNCIL

PERSONNEL METHODS

Recognition and Classification of Human Abilities

During the last decade there has grown up in industry a new branch of technology. It has received the appropriate descriptive name of human engineering. The development has come about through an increasing demand for means to assist managers in selecting men better suited, from the points of view of employee and of employer, to the work they have to do. There is wide demand for reliable information about the methods which have appeared in the form of mental tests, trade tests, rating scales, and other means of discovering human qualifications.

Standardized tests and measurements are widely sought by engineers, but the hazards incident to the activities of charlatans prevent the full utilization of this contribution of modern science. Recognizing the importance of the movement and the need for careful scientific appraisal of available methods, the National Research Council has initiated various activities for the benefit of managers who are dealing with human problems. To this end the Research Information Service of the Council is giving attention to the compilation of reliable information about personnel matters.

As a free clearing-house for the promotion of research and its applications in industry, the Research Information Service is prepared to furnish critical information about modern personnel methods. Among the mechanisms especially designed for this informational service, there is maintained a personnel file in which consulting psychologists, personnel specialists, and other reputable experts on problems of human adjustment are listed. Files of information about available tests and their particular usefulness are also maintained.

With specialists on these problems in the Council offices and with files of information at their disposal, electrical engineers may profitably appeal to the Research Information Service for facts about methods of personnel classification. All communications should be addressed to: Research Information Service, National Research Council, Washington, D. C.

World Economic Situation for 1923

By Secretary of Commerce, Herbert Hoover

The following summary has been prepared in response to numerous requests for a New Year's statement upon the World Economic Situation.

The following summary of the world's economic situation and prospects is based upon the special investigation of the Department's representatives in each foreign country.

In the large view the world has made distinct economic progress during the past year and the conditions are very favorable to continued progress during 1923. There are in exception three or four states in Europe which give continued anxiety, but these exceptions should not obscure the profound forces of progress elsewhere over the whole world. In the main even in these areas of uncertainty the difficulties are to a large degree fiscal and political rather than commercial and industrial.

During the year the world generally has gained in social stability: Bolshevism has greatly diminished and even in Russia has been replaced by a mixture of socialism and individualism; at least active war has ceased for the first time since 1914; famine and distress have diminished to a greater degree this winter than at any time since the great war began; production has increased greatly during the past year; unemployment is less in world totals that at any time since the armistice; international commerce is increasing; the world is now pretty generally purchasing its commodities by the normal exchange of services and goods, a fact which in itself marks an enormous step in recovery from the strained movements of credit and gold which followed the war.

In our country unemployment has ceased to be a problem and we are indeed upon an economic level of comparatively great comfort in every direction except for the lag of recovery in some branches of agriculture. Even in this field there has been a distinct improvement in prices in the past twelve months and its troubles are mostly due to over production in some lines. Our manufacturing industries are engaged well up to the available labor; industrial production has enormously increased over last year; real wages and savings are at a high level. Our transportation and housing show great gains in construction, though we are yet behind in these equipments. Both our exports and our imports are again increasing after the great depression and are today far above pre-war levels.

Outside of Europe the whole world has shaken itself free from the great after-war slump. The economic wounds of Asia, Africa, Latin America, and Australia from the war were more the sympathetic reaction from slump in the combatant states than direct injury. Their production and commerce have recovered to levels above pre-war. The enforced isolation of many areas in Latin America and Asia during the war has strengthened their economic fibre by increased variety of production and has contributed vitally to their effective recovery.

In Europe, England together with the old neutral nations are making steady progress in production and diminishing unemployment. Their trade and commerce are improving; their governmental finances are growing stronger; their currencies that are not already on a gold basis are steadily approaching par; and their exchanges are more stable. The combatant states on the Continent are slower in recovery. Even these nations, including Russia, have shown progress all along the line in commercial, industrial, and agricultural fields although the harvests suffered in some spots. Some of these nations such as Italy, Belgium, The Baltic States, Poland, Czechoslovakia, and Hungary show increasing political and social stability and improvement in their Governmental finances. In Germany and some minor states in southeastern Europe governmental finance and political difficulties threaten to overwhelm the commercial and industrial recuperation already made.

The continued maintenance of armies on a greater than pre-war basis in the old Allied states maintains political uncertainty, lowers productivity, and retards the balancing of budgets with consequent cessation of direct or indirect inflation. Disarmament and the constructive settlement of German reparations and the economic relations of states in southeastern Europe are the outstanding problems of Europe, and their adjustment to some degree will affect the progress of the rest of the world. The more general realization during the past year of the growing menace of these situations and the fundamentals that underlie their solution is in itself some step toward progress. Their solution would mark the end of the most acutely destructive forces in the economic life of the world which still survive the war.

Economic forecast can not amount to more than a review of tendencies and a hazard in the future. The odds are favorable for 1923; the world begins the year with greater economic strength than a year ago; production and trade are upon a larger and more substantial basis, with the single exception of the sore spot in Central Europe. The healing force of business and commerce has gained substantial ascendency over destructive political and social forces. There is ample reason why there should be continued progress during the next twelve months.

PERSONAL MENTION

H. A. Pratt is now connected with the Elevator Supplies Company, Inc., Hoboken, N. J.

H. P. Sparkes is now connected with the Westinghouse Electric & Mfg. Company, Pittsburgh, Pa.

H. G. Howard has resigned as Chief Engineer of the Mexican Light & Power Co., and is now associated with the Lord Cowdray interests in Chile.

Kempster B. Miller has resigned as General Manager of the North Electric Mfg. Co., Gallion, Ohio, to enter the consulting engineering field in Pasadena, Cal.

Claude C. Brown has become connected with the California State Railroad Commission, as Steam Engineer. He was formerly with the California & Hawaiian Sugar Refining Co.

Max C. Richardson, formerly connected with the Hoover Suction Sweeper Co., at North Canton, O., and is now connected with the Long-Bell Lumber Co., at Kelso, Washington.

Jesse Huff, formerly of the United States Patent Office Examining Corps., has resigned to become associated with the Patent Department of the General Electric Company at Schenectady, N. Y.

J. L. Kirkpatrick has resigned his position with the Bell Telephone Company to become General Manager of Installation of the Western Electric Company, with headquarters in New York City.

Fred M. Rosenweig, who has been located in the Chicago office of the Regan Safety Devices Co., is now located in Niagara Falls, N. Y. with the same company, as engineer in charge of development work.

Jesse B. Lunsford has been detached from duty in the office of the Inspector of Engineering Material, U. S. N., New York, and has been transferred to the Bureau of Engineering, Navy Dept., Washington, D. C.

Alexander Macomber of the engineering firm of Macomber & West, Boston, has been elected Treasurer of the Charlestown (Mass.) Gas and Electric Company. He will continue his active connection with his engineering firm.

Norman A. Lougee has become associated with Stone & Webster, Inc., Boston, Mass., as an engineer in the Electrical Division. Mr. Lougee was formerly in the consulting engineering laboratory of the General Electric Company.

Ernest V. Pannell has just returned to New York after a long stay in Japan. His work has been connected with the use

and installation of steel core aluminum conductors for the present extensive transmission line construction in that country.

CAPTAIN JAMES B. ARTHUR, Engineers, U. S. A., until recently in charge of the electrical course at the Aberdeen Proving Grounds, Maryland, has returned to civil life as an engineer in the electrical division of Stone & Webster, Inc., Boston, Mass.

GANO DUNN, Past President of the Institute, has been appointed by the Council of the Institution of Electrical Engineers, of Great Britain, to be the Local Honorary Secretary of the Institution for the United States in place of the late Mr. George G. Ward.

H. R. VAN DEVENTER has been appointed vice-president in charge of Research, Manufacturing and Patent Development of the Dublier Condenser and Radio Corporation, New York City. Mr. Van Deventer was formerly connected with the Westinghouse Electric & Mfg. Co.

THOS. W. WOOTTON, formerly connected with the Hydro Electric Dept., Government of Tasmania, and later with the General Electric Company, has resigned to accept a position with the engineering department of the Adirondack Power & Light Corporation, Schenectady, N. Y.

J. FRANKLIN STEVENS, of Philadelphia, formerly a Manager and a Vice-President of the Institute, is enjoying a tour of the world, accompanied by Mrs. Stevens.

Their trip began in June 1921 by a visit to Alaska; then to the Hawaiian Islands, American and British Samoa, the Fiji and Tonga Islands, New Zealand, Australia, the Celibes, Borneo, and Java. When last heard from Mr. Stevens was in Batavia and expected to be in Singapore until about January 1, and then to proceed to Indo China, China, Philippines, India, and thence through Europe, reaching home some time during 1923.

Obituary

CAPTAIN ROBERT W. HEMPHILL, JR. died, December 8, 1922.

FRANK J. BAKER, vice-president of the Public Service Company of Northern Illinois, died suddenly on December 18, 1922. Mr. Baker was a member of the A. I. E. E.

WILLIAM JARED CLARK, advisory manager of the railway department of the General Electric Company, having been active in the management of that corporation for many years, died at his residence, 251 W. 92nd St., New York City, in his sixty-ninth year. He was born at Derby, Conn. He was a pioneer in the commercial development of electric railways, and helped obtain the charter for the first one designed for freight traffic. During his long service with the General Electric Co. he had been manager if its railway and foreign departments and manager of its London office and was active in politics for many years. He is survived by his wife and two sons.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give nformation concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES (NOV. 1-30, 1922)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

ALASKAN ENGINEERING COMMISSION.

By Joshua Bernhardt. N. Y. & Lond., D. Appleton & Co., 1922. (Institute for Government Research. Service monographs of the United States Government, No. 4). 124 pp., 9 x 6 in., cloth. $1.00.

This monograph, prepared for the Institute for Government Research, follows the general plan adopted for the series. It covers the work of the Alaskan Engineering Commission from its creation in 1914 to 1921, in constructing the U. S. Government Railroad and in the various other activities that devolved upon it. The account is historical, descriptive and financial. It gives a concise summary of information suited to the needs of government officials, members of Congress and the public.

AMERICAN MALLEABLE CAST IRON.

By H. A. Schwartz. 1st edition. Cleveland, O., Penton Publishing Co., 1922. 416 pp., illus., diagrs., 9 x 6 in., cloth. $7.00.

This book, the only American one on the subject now in print, is the work of a metallurgist with long experience in the industry. The volume opens with a historical account of the development of the malleable industry in the United States from its inception in 1820. The various phases of manufacture are then discussed including the plant, materials, fuels, refractories and melting practise with air, electric, cupola and open-hearth furnaces. Succeeding chapters treat of annealing, molding and pattern-making, cleaning, finishing, inspecting and testing. The final section of the book is a study of the physical, thermal and electrical properties of malleable castings, in which is given much hitherto unpublished material. A selected bibliography of nearly 200 references is given.

A. S. T. M. TENTATIVE STANDARDS, 1922. Phila., American Society for Testing Materials, 1922. 9 x 6 in., cloth. $8.00.

The 1922 issue of tentative standards contains 163 specifications for engineering materials, such as metals, cement, lime, gypsum and clay products, preservative coatings, petroleum products, road materials, coal and coke waterproofing, insulating materials, containers, rubber goods and textiles. These specifications are tentative, that is, they are distributed prior to definite adoption, for the purpose of eliciting criticism.

BERECHNEN UND ENTWERFEN VON TURBINEN- UND WASSERKRAFT-ANLAGEN.

Von Ing. Holl. Dritte auflage. München, R. Oldenbourg, 1922. 181 pp., illus., 10 x 7 in., paper. 225 mk.

Holl's Calculation and Design of Turbine and Water Power Plants was written with the intention to furnish all who are interested in water power plants with a convenient assistant in solving the various problems that arise in calculation and design. To facilitate calculation, the author invented a turbine slide rule, the use of which is explained in this book.

In this edition, which is thoroughly revised, the book is planned to give the designer a concise introduction to all the structural and mechanical details of water power plants, which will not only enable him to determine the turbine system for any projected plant, but will also give information upon the construction required in connection therewith.

DIRECT-CURRENT MACHINERY.

By Harold Pender. N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1922. 314 pp., illus., diagrs., 9 x 6 in., cloth. $3.00.

The author says that he knows of no text-book on direct-current machinery which gives a thorough treatment of the theory and performance of such machines, without at the same time going into the details of design to such an extent as to be confusing to the ordinary undergraduate student. It is with the desire to provide such a text that this book is offered. It presents the theory of direct-current machines, and gives much space to the performance, application and testing of the various types of direct-current generators and motors. The testing methods given are those commonly used in commercial laboratories and by manufacturing companies.

ELECTRIC POWER PLANT ENGINEERING.

By J. Weingreen. 3rd edition. N. Y. & Lond., McGraw-Hill Book Co., 1922. 511 pp., illus., diagrs., 9 x 6 in., cloth.

Intended to provide information on practical problems connected with the control of the generation and distribution of electrical energy. Theoretical discussions are reduced to a minimum, the book being primarily a record of current American practise in power plant engineering. This edition has been thoroughly revised. New material has been added on oil switches, open-air switches, lightning arresters and outdoor substations, and reactive coils and synchronous condensers have been discussed in greater detail.

ELECTRIC TRANSIENTS.

By Carl Edward Magnusson, A. Kalin and J. R. Tolmie. First edition. N. Y. & Lond., McGraw-Hill Book Co., Inc., 1922. 193 pp., diagrs., 9 x 6 in., cloth. $2.50.

An outline of an introductory lecture and laboratory course given at the University of Washington. The purpose of this book is to aid the student in gaining clear concepts of the fundamental principles of transient electric phenomena and their application to quantitative problems. Emphasis is placed on the physical properties of electric transients.

ELEKTRISCHE OFEN.

By Oswald Meyer. Berlin and Leipzig, Vereinigung Wissenschaftlicher Verleger, 1922. 133 pp., illus., 6 x 4 in., boards. $.30.

This little book opens with a short historical review of electric heating processes. Next are discussed the physical foundations, methods of measuring furnace temperatures, structural elements and materials for electric furnaces. This is followed by a chapter devoted to the various types of furnaces, classified by methods of heating. The remaining chapters discuss the use of electric furnaces in various industries, domestic electric apparatus for heating and cooking, electric boilers, etc.

HANDBOOK FOR ELECTRICAL ENGINEERS.

By Harold Pender and W. A. Del Mar. 2d edition. N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1922. 2263 pp., diagrs., tables, 7 x 5 in., fabrikoid. $6.00.

A handbook prepared for the practising engineer. With this end in view, theoretical matters have been segregated into separate articles, and articles dealing with practical matters are confined to the latter. Articles are arranged alphabetically, but a topical list of articles is provided as a guide for consecutive study. Bibliographies are included and cost data are given.

The second edition is about one-tenth larger than the first. A number of entirely new articles has been added, many articles have been entirely rewritten and the remaining subject matter has been thoroughly revised. The editor has been assisted by over forty specialists.

HANDBOOK OF THE NATIONAL DISTRICT HEATING ASSOCIATION.

Greenville, O., D. L. Gaskill, Sec'y.-Treas., 1921. 7 x 5 in., fabrikoid. $5.00.

Prepared by the Educational Committee of the Association, and intended as a working manual of district heating practise, particularly with respect to engineering problems. The material is published in loose-leaf form, arranged in two general divisions, steam and hot water heating. Each of these divisions is subdivided into the following groups: General, Generation, Distribution, Utilization, Metering. In addition to engineering data, commercial information supplied by manufacturers of apparatus, is included.

HUTTE. HILFSTAFELN ZUR I. VERWANDLUNG VON ECHTEN BRUCHEN IN DEZIMALBRUCHE, II. ZERLEGUNG DER ZAHLEN BIS 10000 IN PRIMFAKTOREN. Dritte auflage. Herausgegeben vom Akademischen Verein Hutte. Berlin, Wilhelm Ernst & Sohn, 1922. 83 pp., tables, 8 x 5 in., paper. 2 mks.

Two convenient mathematical tables, for the use of calculators and designers are given in this little book. Table one is a series of common fractions arranged in an increasing series and accompanied by their decimal equivalents, calculated to eleven places. It can be used to translate any decimal fraction into a common fraction, neither term of which will be greater than 100. Table two gives the simplest factors of all numbers not divisible by 2 or 5, from 1 to 10,000 and also shows the prime numbers in this range.

The tables are intended primarily for determining gear ratios for lathes, milling machines, etc., but are adapted for other uses as well. Examples of their use for various purposes are given.

SPARKING PLUGS.

By A. P. Young and H. Warren. Lond., & N. Y., Isaac Pitman & Sons, 1922. (Pitman's Technical Primer Series). 106 pp., illus., diagrs., tables, 6 x 4 in., cloth. $.85.

This little book reviews briefly the history of spark plugs and discusses the general principles of electric ignition. The operation and design of spark plugs is then considered in detail. The questions of electrodes and voltages are treated in detail, with data from researches by the authors. This is followed by a consideration of the composition and properties of spark plug insulators.

STEAM TURBINE; Theory and Practise.

By William J. Kearton. Lond., & N. Y., Isaac Pitman, 1922. 456 pp., illus., diagrs., 9 x 6 in., cloth. $4.50.

In the opinion of Mr. Kearton, many recent books on the steam turbine have been over-developed along certain lines, and few have been generally useful to the student. The present work is written for the student, and should prove useful to engineers and draftsmen desiring a wider knowledge of theory.

After introductory chapters on the properties of steam and entropy, the book treats of the steam turbine cycle, the flow of steam through nozzles and blades, efficiency, lubrication, stresses, critical speed and turbine design. This is followed by descriptions of commercial turbines of various types.

TELEPHONY.

By Samuel G. McMeen and Kempster B. Miller. Chic., American Technical Society, 1922. 943 pp., illus., diagrs., 9 x 6 in., fabrikoid. $5.50.

A descriptive, non-mathematical work covering the entire field of telephone engineering in one volume of reasonable size. Describes the customary types of subscribers apparatus, line systems, switchboards, automatic systems, line construction, central offices, etc. Based on American practise.

THEORY OF WAVE TRANSMISSION.

By George Constantinesco. 2d edition, revised. Lond., Walter Haddon, 1922. 209 pp., tables, 9 x 5 in., cloth. 10s. 6d.

A detailed mathematical exposition of the theory underlying the method of power transmission invented by the author. In this system energy is transmitted from one point to another by means of periodic variations of pressure which produce longitudinal wave pulsations in a column of liquid enclosed in a system of piping connecting the wave generator and the tool or machine. Many advantages are claimed for the method, which has been applied practically to rock drills and other percussive tools and to trigger control in machine guns, and is now being adapted to the production of rotary motion.

Addresses Wanted

A list of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

1.—Thomas E. Carey, c/o Tel. Co., 1175 Osage St., Denver, Colo.

2.—Alvarao Daza, Westinghouse International Co., Royal Bk. of Canada Bldg., Havana, Cuba.

3.—William R. Dwyer, 134 N. Lowell Avenue, Syracuse, New York.
4.—Edward J. Ford, P. O. Box 303, E. Pittsburgh, Pa.
5.—J. M. Mercer, Bristol House, Holborn Viaduct, London, E. C., England.
6.—Robert W. Merritt, 845 So. Gramercy Place, Los Angeles, Calif.
7.—Thomas H. Parker, 1839 Tulare St., Fresno, Calif.
8.—Geo. P. Portejoie, National Farming Mach. Ltd., Montmagny, P. Q., Canada.

Past Section and Branch Meetings

PAST SECTIONS MEETINGS

Akron.—November 28, 1922. Subject: "The Story of an Electric Meter." Speaker: Mr. R. J. Andrews, of the Sangamo Electric Co. Attendance 41.

Baltimore.—November 17, 1922. Subject: "New Developments in Power Plants." Speaker: Prof. A. G. Christie, of Johns Hopkins University. Attendance 70.

November 24, 1922. Subject: "Manufacture of Incandescent Lamps." Speaker: Dr. Schaleford. Attendance 85.

Boston.—November 23, 1922. There was a dinner for the speakers and a smoker for the members previous to the meeting. Subjects: "The Development of Lighter-than-Air Ships" by Mr. Edward Schildhauer, and "The Development of Heavier-than-Air Machines," by Prof. E. P. Warner. Attendance 270.

Cincinnati.—November 9, 1922. Subject: "Electric Furnaces in Metallurgical Operations," by Mr. E. F. Collins, Industrial Heating Engineer of the General Electric Co., and Mr. Frank F. Brooke, Chief Engineer, Wm. Swindell & Bros. Discussion followed. Attendance 260.

Cleveland—November 23, 1922. Subject: "Alternating High-Speed Elevators." Speaker: Mr. E. B. Thurston, Electrical Engineer of the Haughton Elevator Co. Discussion followed. Attendance 55.

Columbus.—November 24, 1922. Subject: "A Review of the Fundamental Principles of Radio," by Captain H. W. Webbe, U. S. Signal Corps, and "Broadcasting," by Prof. R. A. Brown. Attendance 57.

Connecticut.—November 23, 1922. Joint meeting with the Waterbury Branch, A. S. M. E. Subject: "Waterbury's Power Supply," by Mr. Irvin W. Day, Mr. A. J. Campbell, Mr. Paul Spencer and Mr. Rollin Norris. Attendance 160.

Denver.—November 24, 1922. Ladies' Meeting. Demonstration of telephone by women in the business, supplemented by motion picture "Behind Your Telephone." Attendance 46.

Erie.—November 21, 1922. Joint meeting with the Northwestern Engineering Society, A. S. M. E. and A. I. E. E. There was an illustrated lecture by Mr. C. M. Ripley of Schenectady, on "What Electricity Has Done for Civilization." Attendance 120.

Fort Wayne.—November 23rd, 1922. Subject: "Automatic Switching of Telephone Circuits." Speaker: Mr. F. T. Madsen. Animated circuit diagrams illustrated the talk. Attendance 80.

Indianapolis-Lafayette.—November 24, 1922. Subjects: "Safety First Measures," by Mr. F. A. Montrose, and "The Storage Battery in the Telephone Plant," by Mr. D. D. Sandefur. Attendance 58.

Ithaca.—November 17, 1922. Subject: "Problems in the Development of Modern High-Voltage Transformers." Speaker: Mr. H. Boyajian. Slides were shown. Attendance 225.

Los Angeles.—October 25, 1922. Subject: "The 220-Kv. Transmission Line of the Southern California Edison Company." Speaker: Mr. R. J. C. Wood. Discussion. Attendance 77.

Lynn.—October 25, 1922. There was an exhibition of the latest development of the moving picture as exemplified in "The Glorious Adventure," a picture showing natural coloring. Attendance 455.

November 8, 1922. Ladies' Night. Lecture by Mr. Donald B. MacMillan "In Unknown Baffin Land." The lecture was illustrated by slides and moving pictures. Attendance 825.

November 23, 1922. Subject: "The Arrangements of Atoms in Crystals." Speaker: Dr. Wheeler P. Davey. These were by lantern slides. Attendance 175.

New York Section.—On the evening of December 13th, the New York Section of the Institute held a meeting jointly with the New York Sections of the Mechanical, Mining and Civil Engineers. The meeting was held in the auditorium of the Engineering Societies Building, 33 West 39th Street, New York, attendance about 200. The principal speaker of the evening was Mr. John T. Pratt, Chairman of the National Budget Committee and his subject, "The Elimination of Waste in Government Engineering." Mr. Pratt explained the purposes of the Budget act and pointed out the fact that no matter how rigidly bureau chiefs might economize, cutting down their requirements to a minimum and how closely appropriations under that act were adhered to, it was possible to overthrow the whole idea of limited government expenditures through the passage by Congress of acts calling for special appropriation, such as the Bonus Bill, etc. Mr. Pratt urged that people keep their eyes open for just such raids on the Federal treasury and use their influence to suppress them. The discussion following was participated in by General Wm. C. Langfitt, Frederick Feiker and C. T. Chenery.

Oklahoma.—December 9, 1922. Inspection trip of the Cosden Refinery at Tulsa. Attendance 42.

Philadelphia.—December 11, 1922. Subject: "Furnishing Telephone Service to a City, such as Philadelphia." Speaker: Mr. Francis J. Chesterman. A Christmas dinner was served to 50 guests and members before the meeting. Attendance 158.

Pittsburgh.—November 14, 1922. Subject: "Status of Railway Electrification." Speaker: Mr. Norman W. Storer. Discussion followed. Attendance 252.

Pittsfield.—November 23, 1922. Subject: "Grinding and Abrasives." Speaker: Mr. Charles H. Norton. Attendance 150.

Portland.—November 14, 1922. Subject: "Giving Labor the Place to Which it is Entitled." Speaker: Mr. Norman F. Coleman. Attendance 38.

Providence.—November 17, 1922. Subject: "An Engineer's Impression of Japan." Speaker: Mr. Dana M. Wood. Attendance 40.

Rochester.—November 20, 1922. Joint meeting with the local section of the American Chemical Society. Subject: "Combustion from the Industrial Standpoint." Speaker: Prof. W. K. Lewis, of Mass. Inst. of Tech. Attendance 200.

St. Louis.—October 18, 1922. Subject: "The Process of Manufacturing Steel from the Mining of the Ore in Sequence to the Rolling of the Finished Material." Speaker: Mr. G. A. Richardson. Attendance 35.

November 22, 1922. Subject: "Improvements in Street Railway Service since the Beginning of the Old Horse Car Lines." Speaker: Col. A. T. Perkins. Attendance 105.

San Francisco.—November 3, 1922. Subject: "Relays as Applied to Large Power Systems." Speaker: Mr. Robert Treat. Attendance 85.

Schenectady.—November 3, 1922. Subject: "Some Aspects of European Railway Electrification." Speaker: Mr. W. B. Potter. Discussion followed. Attendance 200.

November 17, 1922. Subject: "Hydroelectric Development." Speaker: Mr. W. M. White. There were numerous slides shown, and a discussion ensued. Attendance 230.

December 1, 1922. Subject: "Magnetism from an Engineering Viewpoint." Speaker: Mr. L. T. Robinson. Attendance 170.

Seattle.—November 15, 1922. Subject: "Geological History of our Water Power Situation." Speaker: Dean Landes. The lecture was illustrated by lantern slides. Attendance 62.

Spokane.—October 20, 1922. Joint meeting with the Associated Engineers of Spokane. Subject: "The Queenston-Chippewa Power Project." Speaker: Mr. R. L. Heam. Attendance 40.

November 6, 1922. Subject: "Power Development of the West." Speaker: Mr. W. S. Murray. Attendance 52.

Toledo.—November 22, 1922. Subject: "Fundamental Principles Underlying Radio Communication." Speaker: Mr. J. W. B. Foley. There was an interesting discussion. Attendance 46.

Toronto.—November 24, 1922. Subject: "Modern Electrical Practise to Prevent Accidents." Speaker: Mr. Wills MacLachlan. A number of members contributed to the discussion that followed. Attendance 82.

December 8, 1922. Joint meeting with the Toronto chapter of the Illuminating Engineering Society. Subject: "Street Lighting, Street Traffic Control and City Planning." Speaker: Mr. A. J. Sweet. Attendance 135.

Urbana.—November 14, 1922. Subject: "Inspection and Grading of Electric Service." Speaker: Mr. J. Howard Mathews. Attendance 50.

Utah.—November 22, 1922. Subject: "Radio," by Prof. Tugman, Mr. J. G. McCollum, and Mr. J. C. Painter. Extensive discussion followed. Attendance 125.

Vancouver.—November 3, 1922. Business meeting. Attendance 14.

Washington, D. C.—October 10, 1922. Subject: "Performance Tests on Radio Receiving Sets." Speaker: Mr. L. E. Whittemore, of the Bureau of Standards, and "Electron Tubes," by Dr. J. H. Dellinger. Attendance 237.

October 31, 1922. Mr. E. R. Whitney, President of the Commercial Truck Co. of America delivered a lecture covering the development of electric street trucks in local delivery service and some details of their manufacture. Attendance 275.

Worcester.—November 16, 1922. Subject: "Electric Meters." Speakers: Messrs. C. D. Knight, G. M. Hardy and A. B. Sprague. Attendance 64.

PAST BRANCH MEETINGS

University of Alabama.—October 9, 1922. Business meeting. Attendance 14.

October 23, 1922. Meeting adjourned in favor of religious meeting held at same hour.

November 7, 1922. Subject: "Tips to the Young Engineer." Speaker: Prof. McDonald. Attendance 21.

November 21, 1922. Subject: "The Engineer in Society." by Prof. Maxwell and "The A. I. E. E. and What It Is," by Dr. Bauder. Attendance 19.

University of Arizona.—November 15, 1922. Subject: "Radio." Speaker: Mr. L. R. Wilson. A radio concert and a social hour followed. Attendance 30.

University of Arkansas.—November 28, 1922. Subject: "Engineering Organizations," by Dean W. N. Gladson. A motion picture was shown by courtesy of the Sangamo Electric Co., entitled "The Story of an Electric Meter." Attendance 69.

Armour Institute of Technology.—November 16, 1922. Subjects: "The Engineer in the Bond Business," by Mr. D. S. Chase, "Economic Waste and Efficiency," by Prof. Freeman, and "Being Prepared for the Emergency," by Prof. Moreton. Attendance 50.

December 7, 1922. Subject: "Trackless Train System of Industrial Haulage." Speaker: Mr. Klein, of the Mercury Manufacturing Co. Moving pictures were shown. Attendance 45.

Bucknell.—November 15, 1922. Subject: "Freshmen and the Electrical Engineering Course." Speaker: Prof. Rhodes. A social meeting followed. Attendance 52.

University of California.—November 22, 1922. Joint meeting of the A. I. E. E., A. S. M. E. and A. S. C. E. Subject: "The Construction and Practical Application of the Gyroscope." Speaker: Mr. R. B. Lea, of the Sperry Gyroscope Co. Attendance 180.

Carnegie Inst. of Tech.—November 16, 1922. Subject: "Railway Signaling." Speaker: Dr. L. O. Grandahl. Attendance 31.

Case School of Applied Science.—November 24, 1922. Subject: "Electrical Measuring Instruments." Speaker: Mr. R. D. Hickok. Attendance 46.

University of Cincinnati.—November 16, 1922. Business meeting. Subject: "The New Polarized Search Light." Speaker: Prof. R. C. Gowdy.

November 22, 1922. Joint meeting of all the engineering societies at the university. Subject: "What the American Legion is Doing." Speaker: Mr. Gilbert Bethman. Attendance 300.

December 9, 1922. Annual dinner. Attendance 75 couples.

Clarkson College of Technology.—October 11, 1922. Business meeting. Attendance 12.

Colorado Agricultural College.—October 16, 1922. Business meeting. Attendance 10.

November 13, 1922. Subject: "The Deadliness of an Electric Shock." Speaker: Mr. Jordan. Attendance 10.

University of Colorado.—December 6, 1922. Subject: "Telephone Transmission Problems." Speaker: Mr. Bonney. Slides were shown. Attendance 48.

Iowa State College.—November 1, 1922. Subject: "The Sangamo Meter." Speaker: Prof. F. D. Paine. Moving picture "The Story of an Electric Meter." Attendance 97.

Kansas State College.—November 13, 1922. Motion pictures were shown: "The Story of an Electric Meter" and "The Power Behind the Button." Attendance 70.

November 27, 1922. Subject: "Vacuum Feed for Automobiles" by Mr. A. M. Seizler, "Telephotography and Television," by Mr. H. Crall, and "Fortress Monroe's Fortifications," by Mr. L. E. Jennings. Attendance 84.

University of Kansas.—November 8, 1922. Subject: "My Inspection Trip Through the United States and Europe." Speaker: Mr. H. W. Herrington. Attendance 24.

Lafayette College.—October 14, 1922. Subject: "The Question of Illumination," by Prof. King. Attendance 21.

October 28, 1922. Practical application of light to the design of a lighting system, worked out conjointly by the whole branch. Attendance 21.

November 11. Subject: "The Future Outlook of an Electrical Engineer" by Prof. King. Attendance 19.

November 15, 1922. Joint meeting of the engineering societies and illustrated lecture by Dr. W. G. Hatt on "The Problems of Highway Engineering." Attendance 21.

Lehigh University.—November 23, 1922. Subject: "Communication Service." Speaker: Mr. F. E. Galbraith. Attendance 85.

Lewis Institute.—November 15, 1922. Business meeting. Attendance 18.

November 17, 1922. Inspection of the Drake Hotel in Chicago. Attendance 27.

November 22, 1922. Discussion of proposed trip to Western Electric Company's plant. Attendance 15.

Marquette University.—November 13, 1922. Subject: "Efficiency in Industry as Determined by Time Studies." Speaker: Mr. E. P. Reilly. Attendance 28.

School of Engineering of Milwaukee.—November 24, 1922. Subject: Substation Operation." Speaker: Mr. O. M. Ward. Attendance 30.

University of Minnesota.—November 15, 1922. Subjects: "What the A. I. E. E. is and What It Stands For," by Prof. Ryan, "The Development of Electrical Engineering at the University of Minnesota," and "A Student's Attitude Toward the A. I. E. E.," by Mr. Le Roy Grettum. Attendance 75.

December 8, 1922. Subjects: "The Transportation Phase of the Great Lakes-St. Lawrence River Project," by Mr. Shenehon, and a general talk on the St. Lawrence Project, by Frank Wilson, his remarks being based on Mr. Cooper's paper in the November issue of the JOURNAL. Two reels of moving pictures were shown, depicting the history and manufacture of the storage battery and the other a war film. Attendance 75.

Montana State College.—November 14, 1922. Subject: "Engineering, Its Progress and Progress of the Engineer." Speaker: Mr. F. W. Jordan. Attendance 108.

December 5, 1922. Lecture on the General Electric Company's Works at Schenectady by Mr. R. C. Hogen. Attendance 108.

University of Nebraska.—November 15, 1922. Subjects: "Automatic Stations and Substations," by Mr. Frank J. Moles, "Toll Testing and the Work and Responsibilities of a Toll Wire Chief," and Mr. L. P. Shildneck talked on his experiences in the Construction Department of the Commonwealth Edison Company. Attendance 26.

University of North Carolina.—November 16, 1922. Subjects: "Transformer Inspection," by Mr. H. P. Rlurgenschmitt, and "Mountain Lumbering," by Mr. W. R. Harding. Attendance 26.

University of North Dakota.—November 20, 1922. Subject: "North Dakota Lignite Coal," by Mr. Charles W. Randall. Attendance 12.

Notre Dame University.—November 27, 1922. Subjects: "Regenerative Braking," by Mr. George Butterfield and "Inspection of Power Plants to Prevent Breakdowns," by Mr. Michaels of the Indiana and Michigan Electric Co. Attendance 41.

Ohio Northern University.—November 8, 1922. The members of the A. I. E. E. were the guests of the A. S. M. E. branch. A series of industrial moving pictures were shown.

December 7, 1922. Subject: "Economics and the Engineer," by Prof. Brinkely. Attendance 15.

Ohio State University.—November 23, 1922. Social meeting for freshmen. Attendance 60.

November 24, 1922. Prof. C. A. Norman gave a talk on his engineering experiences in Russia before the revolution. Attendance 50.

December 8, 1922. Subject: "The Effects of Superimposed A-C. and D-C. Fields on Magnetic Circuits," by Dr. Alva W. Smith. Attendance 75.

Oregon State Agricultural College.—November 22, 1922. The moving picture "The Story of an Electric Meter" was shown, by courtesy of the Sangamo Electric Co. Attendance 100.

Purdue University.—November 14, 1922. Subject: "The Manufacture of Electric Lamps," by Mr. O. T. McIlvaine. Slides were shown illustrating the development of electric lights, and a moving picture was shown entitled "The Light of a Race." Attendance 50.

November 28, 1922. Subject: "Telephone Engineering," by Prof. R. V. Achatz. Attendance 15.

Rensselaer.—November 14, 1922. Subject: "Broadcasting," by Prof. W. J. Williams. Attendance 225.

Rutgers.—November 23, 1922. Two students read papers from technical electrical journals. Attendance 74.

University of Southern California.—November 22, 1922. Subject: "The Alexanderson Alternator and Its Use in Radio," by Mr. Ivan Summers. Attendance 13.

Syracuse University.—November 2, 1922. Subjects: "Maintenance and Care of Small Motors," by Mr. Clarence Chase, "Electrical Theory of Magnetism," by Earl B. Clarke, and "The Steam Plant of the Buffalo General Electric Company." Attendance 17.

November 9, 1922. Subjects: "The Manufacture of the Mazda Lamp," by Mr. Harold A. Olson and "The Development of Power on the Snake River," by Mr. Paul Moore. Attendance 20.

November 16, 1922. Subjects: "Bearings," by Mr. Lyle Edwards and "The Manufacture of a Standard Wireless Receiver," by Mr. Lloyd E. Lawrence. Attendance 19.

November 23, 1922. Subject: "Watt-hour Meter and Its Use in Single-Phase Lighting Circuits," by Mr. Cooper. Attendance 22.

University of Texas.—November 6, 1922. Subjects: "The Limitations of Steam and Electric Railways," by Prof. J. M. Bryant, "Electric Railway Systems in the United States," by Mr. C. H. McCollough and "European Practise in Electric Railway Construction," by Mr. L. O. Vogelsang. Attendance 31.

Virginia Military Institute.—November 24, 1922. Joint meeting with A. S. M. E. and the American Association of Engineers.

Virginia Polytechnic Institute.—November 13, 1922. Subject: "Electric Transmission for Automotive Machinery." Attendance 151.

University of Virginia.—November 23, 1922. Subjects: "Management of Public Utilities," by Mr. Bryant White, "The Progress of the Charlottesville & Albermarle Railway," by Mr. John L. Livers and "Public Relations of Utilities," by Mr. Oliver Martin. Attendance 56.

West Virginia University.—November 20, 1922. A number of short papers were presented by the following: Messrs. Moffet, Winter, Chabaurel, Addis, Lowe, Richards, Kellerman, Park, Lee, Copley, Myers and Barone. Attendance 32.

December 11, 1922. Papers were presented by the following: Messrs. Pitsenberger, Kellerman, Brown, Hall, Snyder, Rosier, Davis, Boyers, Steele and Hill. Attendance 29.

University of Wisconsin.—November 29, 1922. Subject: "Signal Corps and Signal Developments in Armies," by Mr. H. R. Melcher. Attendance 21.

Employment Service Bulletin

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

MEN AVAILABLE.—Under this heading brief announcements will be publishedwithout charge to the members. Announcements will not be repeated except upon request received after a period of three months, during which period names and records will remain in the active files.

NOTE.—Notices for the JOURNAL should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York, N. Y.****, the employment clearing house of the National Societies of Civil, Mechanical, Mining and Electrical Engineers.*

Notices for the JOURNAL are not acknowledged by personal letter, but if received prior to the 16th of the month will appear in the issue of the following month.

All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case ***and forwarded to EMPLOYMENT SERVICE****, as above.*

Replies received by the bureau after the position to which they refer has been filled will not be forwarded, and will be held by the bureau for one month only.

OPPORTUNITIES

DESIGNER. Experienced in machine tools, jigs and fixtures. Shop experience desirable. Want man who can work into position of Chief Draftsman or Chief Engineer. Application by letter. Salary not stated. Location, Cleveland, Ohio. V-2028.

SALES ENGINEER with public utility experience to sell bonds of public utilities. Commission basis. Application by letter. Location, Phila., Pa. V-2070.

SALES ENGINEERS who are thoroughly familiar with oil burners and equipment capable of selling new highly efficient product to industrial users and power plants. Application by letter only. Commission basis. Headquarters, N. Y. C. V-2967.

COOPERAGE SUPERINTENDENT. Company manufactures 1000 barrels per day (liquid and non-liquid proof barrels). Standard Holmes machine used. Familiar with all details of barrel manufacture. Application by letter stating age, education and experience. Salary not stated. Location, New Jersey. V-3070.

DRAFTSMEN. Electrical, experienced in design of indoor and outdoor substations and equipment. Mechanical, experienced on gas plant equipment. First class men only, qualified to act as squad bosses. Technically trained men with at least 10 years' experience. Application by letter. Salary not stated. Location, Pennsylvania. V-3073.

GRADUATE ELECTRICAL ENGINEER to act as asst. to engineer of electric distribution. Will have immediate supervision over electrical inspectors. In addition to having had several years' experience in all branches of distribution work, should have had experience in handling inspectors and directing work. Should be between 30-40 years with an enthusiasm for work; good opportunity. Desirable that man be a protestant, native born American. Application by letter. Salary not stated. Location, N. Y. State. V-3087.

ELECTRICAL INSPECTORS (2) to layout distribution and street lighting circuits, make up estimates and plans for extensions and alterations on transmission and distribution circuits. Need not be college graduate, but should have some technical training and at least two or three years' experience in this work. Application by letter. Salary not stated. Location, New York State. V-3088.

ELECTRICAL DRAFTSMAN for public utility company in northern N. Y. Application by letter. V-3090.

YOUNG MAN to take charge of warehouse; keep track of stock, inventory, shipments, etc. Location, small town. Opportunity to work up in rapidly growing concern and transfer to other warehouses. Should have some warehouse experience in packing and shipping. Application by letter. Location, N. Y. State. V-3092.

SALESMAN should have working knowledge of application of time records to manufacturing costs and clear idea of the principles of electricity as applied to magnetic circuits. Must be situated to approach and work with executives of large organizations and in a position to work on a strictly commission basis. Application by letter. Headquarters, New York City. V-3093.

MECHANICAL ENGINEER with fire protection experience. Application by letter stating age, education and experience in detail. Salary not stated. Location, New York City. V-3095.

PARTNER with engineering ability ready to invest minimum of $35,000 part of which may be paid from earnings, desired for long established prosperous business in special machinery. Founder of business unable to properly care for present organization and expansion. Application by letter. Location, New York City. V-3098.

EASTERN SALES MANAGER for company manufacturing varnish and winding coils. Graduate engineer. Traveling position. Application by letter. Salary not stated. Location, New England. V-3104.

MECHANICAL AND POWER ENGINEER, experienced in power plant practise, operation, calculations, utilization, and departmental distribution of power, steam, water, coal, etc., in large manufacturing plant located in Wisconsin. Application by letter stating age and salary expected, experience in detail. V-3105.

YOUNG MAN to act as technical assistant to plant betterment engineer. Study of plant records as to performance and operating costs, test reports of boilers, turbines, etc., and by means of curves and tabulations. Some general engineering calculations involved; knowledge of boiler heat balance computations would be helpful. Technically trained applicants with experience preferable. Application by letter stating age, education and experience. Salary not stated. Location, New York City. V-3111.

GRADUATE M. E. or C. E. with 2-3 years' experience, preferably along combustion lines. Field work, testing, office work, etc. Application by letter (typewritten). Salary not stated. Location, Pennsylvania. V-3116.

SUPERINTENDENT of power and mechanical maintenance for textile plant in India. Power plant with all American machinery, electric transmission. Must have good experience, good health and habits, and not over 35 years old. Three year contract. Application by letter. Salary not stated. V-3117.

DESIGNING DRAFTSMAN with heating and ventilating experience. Experienced engineers only will be considered. Application by phone. Location, New York City. V-3131.

ASST. PROFESSOR of practical mechanics in charge of mechanical drawing. Location, Lafayette, Indiana. V-3138.

ENGINEER experienced in radio work with technical training. Man who has done actual work on mechanical apparatus. Should be able to demonstrate outfits. Application in person. Location, New York City. V-3133.

RECENT COLLEGE GRADUATES for service in Far East. Must be university graduates in M. E., unmarried, between 22-28 years of age and preferably, either recent college graduates or with slight experience in engineering, one or two years. Only men of good personality and bearing and American citizens considered. Application by letter. Salary not stated. V-3136.

YOUNG MAN, age 24-28, high school or preparatory school, with at least 2 years' technical education along electrical lines. Executive ability, tact, ability to handle men and women employees. Lamp testing dept. and work involves supervision of detail in handling of testing work as well as test reports and statistics. Knowledge of office routine of advantage in connection with clerical and statistical method. Application by letter stating age, education and experience. Salary not stated. Location, N. Y. C. V-3139.

ELECTRICAL ENGINEER. Technical graduate with experience in design and inspection of overhead and underground electrical distribution and transmission systems, substation and steam electric generating stations in the engineering dept. of large public utility. Also, structural engineer with experience in design and construction of reinforced concrete and other structures. Application by letter. Salary not stated. Location, Texas. V-3140.

TECHNICAL GRADUATE, preferably electrical who has had considerable experience on design and layout of electrical apparatus in power houses. Experience in transmission work, although not absolutely essential, will be valuable. Work will embrace interior layout of electrical apparatus on proposed new power plants and substations. Application by letter. Salary will depend on qualifications, including initiative and possibilities of development. Location, New York State. V-3141.

HIGH-CLASS SALESMEN experienced in selling power plant apparatus. Application by letter stating age, education and experience. Salary not stated. Location, New York City. V-3142.

EXPERIENCED OPERATOR for 1000-ton steam-hydraulic forging press. One who has had

a wide experience on heavy forged shafting, heavy pressed flanges and standard oil well equipment. Application by letter. Salary not stated. Location, Pacific Coast. V-3147.

RECENT GRADUATE to take care of office. Must be familiar with conveyors and their application. Some practical experience desired. Temporary. Application in person by appointment. Location, New York City. V-3149.

RECENT GRADUATE to act as manager electric power plant in Cuba or South America. About 30 years old. Must speak Spanish. Application in person. Salary not stated. V-3150.

STRUCTURAL ENGINEER with experience in design and construction of reinforced concrete and other structures for public utilities. Application by letter. Salary not stated. Location, Texas. V-3153.

ROOFING MATERIALS SALES ENGINEER. Previous selling experience in roofing trades important. Excellent opportunity for man with automobile and above requirement to obtain part interest in good business. Application by letter. Salary not stated. Location, New York City. V-3161.

EXPERIENCED ELECTRICAL DESIGNER, with substation and central station work as the principal feature of his training. Work will be in Canada and is in connection with large South American hydroelectrical power station. Application by letter. Salary not stated. V-3162.

ELECTRICAL ENGINEER, who must understand installing of motors and lighting equipment for transmission work, testing and inspection of motors, generators, switchboard and charging equipment and must be able to go into field and secure data. Must be able to inspect work in progress. Application by letter. Future and advancement. Location, N. Y. C. V-3163.

GANG LEADERS heavy locomotive boiler repairs. Riveting and caulking. Must be a thorough chipper and caulker, both hand and pneumatic, and familiar with use of taps, dies and all classes of reaming. Application by letter. Location, Ohio. V-3164.

STAY BOLT GANG. Must be a thorough man on the removing and the replacement of stay bolts. Must be familiar with use of taps and dies on classes of reaming. Application by letter. Location, Ohio. V-3165.

NIGHT GANG LEADER. Must be thoroughly skilled all-around boilermaker. Familiar with high-pressure locomotive repairs and should have experience as general boiler repairman in railway repair shops and have knowledge of various types of locomotive boilers. Application by letter. Location, Ohio. V-3166.

ENGINEERING GRADUATE for research work on materials used in construction of high-grade special electrical apparatus. Magnetic materials, sheet and molded insulations, varnishes, wires and cables, etc., included in the list. Working knowledge of testing machinery and industrial chemistry desirable. Application by letter. Salary not stated. Location, New England. V-3167.

ENGINEER MANAGER to operate and manage light and water plant in town of about 10,000. About 30 years of age with 5-8 years' experience. Married man preferred. Application by letter. Salary not stated. Location, North Carolina. V-3176.

SALES ENGINEER to sell boiler and power plant accessories. Must have New York district experience. Application by letter. Salary not stated. Location, New York City. V-3170.

DRAFTSMEN, preferably designers with engine or air compressor experience. Application by letter giving full particulars. Salary not stated Location, Ohio. V-3173.

ELECTRICAL DRAFTSMAN for power house and substation layout work. Application in person. Salary not stated. Location, New York City. V-3184.

DRAFTSMAN with signal circuit layout and relay protection work experience. Application in person. Salary not stated. Location, New York City. V-3185.

MECHANICAL DRAFTSMEN (3), mill layout and conveying machinery. Temporary. Application by letter. Salary not stated. Location, New York State. V-3188.

HEATING AND VENTILATING ENGINEER with designing and contracting office experience. 5 years' experience required. Power plant experience also required. Application by letter. Salary not stated. Location, Tennessee. V-3189.

INSTRUCTOR. Practical electrical engineer who can interest students in class room instruction, must know code and application. About 30 years old. Not necessarily a graduate. Application by letter. Location, Georgia. V-3193.

ELECTRICAL ENGINEER for electrical design dept. Must have had at least 2 years' experience in design of synchronous motors. Prefer man with enough experience to qualify him to take charge of Synchronous Motor Design Dept., but will consider one with less experience, work under direction of more experienced man. Application by letter. Salary according to training and experience and responsibility which, in our opinion, he is capable of assuming. Location, Missouri. V-3197.

MECHANICAL DRAFTSMEN (6), central station work. Experienced men only in this line of work. Application in person. Salary not stated. Location, New York City. V-3205.

RECENT GRADUATE INSTRUCTOR for pattern making and foundry practise, also mechanical laboratory experience with qualifications to develop into professorship. Single. Application by letter. Salary not stated. Location, North West. V-3209.

ELECTRICAL ENGINEER acquainted with ship electrical work, to write up specifications to take trial trip and make up reports. Application by letter. Location, New York. V-3211.

YOUNG MAN of approximately 35 years of age, who has had at least 5-10 years practical designing experience, particularly in machinery designing, not necessarily in stoker designing, and one qualified to work out practical commercial problems. Application by letter stating age, education and experience. Salary not stated. Location, Indiana. V-3222.

HIGH-GRADE MECHANICAL DRAFTSMEN (2) for Pittsburgh district. Should be thoroughly well educated mechanical engineers with at least 10 years' experience along lines of cranes, marine machinery or steam engines and boilers. Permanent. Application by letter. Salary not stated. Location Pa. V-3224.

SALES ENGINEER on valves, sales promotion work. 4-5 years experience. Very capable man able to take charge of all valve sales and control other salesmen. Application by letter. Salary not stated. Headquarters, New York City. V-3225.

DRAFTSMAN competent to design boiler house and also the buildings for same with its equipment. Opportunity of a man to work into position in the paper business other than as draftsman if he should so desire. Permanence will depend upon man and condition of paper business. Application by letter. Location, Wisconsin. V-3227.

YOUNG MECHANICAL ENGINEER to act as assistant to master mechanic. General supervision of one hundred mechanics in shops and in plant repair work, planning and estimating, repair and minor construction work. Application by letter stating age, education and experience. Salary not stated. Location, New Jersey. V-3228.

DRAFTSMAN on power house construction, buildings, foundations, etc. Must have experience in this line of work. Application in person. Location, New York. V-3231.

YOUNG ENGINEER with knowledge of power plant and drafting. Must have some acquaintance with purchasing and construction. Able to take as well as give orders. Application by letter. Graduate of Columbia Univ. preferred. Location, New York City. V-3232.

RECENT GRADUATE to inspect small power plants report operating conditions and to develop into the business. Application in person. Location, New York City. V-3233.

DRAFTSMAN on steam turbines and power house equipment. 4-5 years' experience desired. Application in person by appointment. Salary not stated. Location, N. Y. C. V-3234.

INDUSTRIAL ENGINEER about 40 years old with woodworking experience. Must be a graduate M. E. Must also have the experience of efficiency engineer. Application by letter. Salary not stated. Location not stated. V-3239.

SALES ENGINEER—Must have had some experience, to sell power house equipment such as grate bars and hand operated stoker. Should have combustion engineering experience. Application in person. Salary not stated. Location, N. Y. C. V-3243.

DETAIL DRAFTSMAN on power plant work. Application by letter. Salary not stated. Location, New York City. V-3248.

YOUNG TECHNICAL GRADUATE with a year or two of drafting experience, to work into purchasing and testing of electrical and mechanical material. Application by letter. Salary not stated. Location, New York City. V-3257.

MEN SKILLED IN CASUALTY INSURANCE. Inspection work, including boilers, engines, flywheels, elevators, public liability and workmen's compensation. Application by letter. Salary not stated. Location, Chicago, Cleveland, Phila. and N. Y. C. V-3255.

MANUFACTURING ENGINEER. Technically trained man in either mechanical or electrical engineering, capable of handling assignments through the process of development and the design of special machinery. Chicago manufacturer. Application by letter giving full particulars stating age and salary desired. Location, Chicago, Ill. V-3259.

ELECTRICAL DRAFTSMEN, familiar with the arrangement and installation of electrical apparatus in sub and central power stations. Should have experience with conduit layouts. (We do not wish designers of electrical apparatus.) Technically trained men with at least 10 years' experience. Application by letter. Location, Pennsylvania. V-3260.

RECENT GRADUATE ELECTRICAL ENGINEERS. Work involves design, manufacture, inspection and testing of rubber, paper and varnished cambric insulated telephone and power cables. Application by letter. Location, N. J. V-3261.

INSPECTOR. Alterations on buildings inside work, partitions, plastering, painting, etc. Man who has had responsible work such as superintendent of construction on large office buildings, who knows the finishing touches. 35 years old. Application by letter. Salary $70-75. Location, New York City. V-3278.

RESEARCH ENGINEER for company manufacturing household appliances. Must be graduate M. E. at least 4 years out of college and should have some experience in research work. Applica-

tion by letter. Salary $175 plus. Location, Ohio. V-3279.

SALES ENGINEER to sell electrical specialties or carry as side line. Application in person. Commission basis. Location, New York City. V-3281.

SUPERINTENDENT. Duties will consist of general supervision of the entire water and light properties, including a transforming and converting station which also contains the pumping machinery. Duties further include maintenance of the distribution system, both water and electric, the setting and reading of meters and the billing and auditing system used in connection therewith. Application by letter. Salary not stated. Location small town in western New York. V-3283.

MECHANICAL OR ELECTRICAL ENGINEER experienced in the manufacture of carbon and graphite brushes, resistance rods, etc. Should have production experience as he will later have development of new department. Application by letter. Location, New Jersey. V-3294.

FOREMAN to take charge of manufacture of electrical porcelain plugs. Must be experienced in high-temperature oil burning kilns. Should also understand mixing of porcelain. Application by letter. Salary not stated. Location not stated. V-3295.

SALES ENGINEER to handle power plant specialty on salary and commission basis. Ready market, unlimited field and little competition. Will have district agency and selection of our sales force. Application by letter. Location, eastern United States. V-3297.

SALES ENGINEER. Manufacturer of electrical apparatus in New York has opening for recent college or technical graduate, first taking a course in factory engineering department, then field work, consisting of searching out new applications and uses for the product, leading to a permanent sales engineering position. Involves some traveling, requires man with engineering instincts, ability to acquire knowledge of industrial processes, of good address, and with persistance in developing new business. Not a ready made job, but an opportunity to build a place in an interesting and growing field. Application by letter giving complete personal information. Headquarters, N. Y. C. V-3302.

YOUNG ELECTRICAL OR CIVIL ENGINEER of 2 or 3 years' experience as office assistant to the general superintendent, doing general detail engineering and cost accounting work. Application by letter. Salary not stated. Location, North Carolina. V-3304.

SALES ENGINEER to sell motors and pumps for large manufacturer. Technical graduate with some practical selling experience preferred. Straight salary, no commission. Application by letter. Location, Texas. V-3305.

SALESMAN for a complete line of electrically operated time recording and indicating equipment, with territories in and adjacent to New York City. Work will be a strictly commission basis, which will pay the properly fitted man an excellent return. Experience with the application of simple time records to factory cost accounting and knowledge of the principles of electricity are needed. Application by letter. Headquarters, Illinois. V-3306.

ELECTRICAL ENGINEER with 4-5 years' experience in public utility work; not necessarily valuation, construction and design will do. Application in person by appointment. Location, New York City. V-3313.

ENGINEER experienced in the applications and sale of high grade electric power equipments. Must be hustlers and willing to start on commission. Application by letter. Headquarters, New York City. V-3315.

OPERATING ENGINEER with N. J. License, 600 boiler h. p. and air compressors. Age about 40. Should be familiar with alternating current and able to handle men. Application in person. Salary not stated. Location, New Jersey. V-3316.

HIGH GRADE SALES AGENTS for the distribution of electric appliances. Application by letter. Salary not stated. Headquarters, Pennsylvania. V-3320.

ELECTRICAL ENGINEER with experience on power plant electrical equipment, substations and transmission lines for construction design work and technical problems connected with the operation of a large public utility system. Technical ability together with experience on similar work necessary. Replies must give details of education, experience, personal characteristics, references and salary desired. Application by letter. Location, West Va. V-3324.

SALES ENGINEER to cover a part of the eastern section of this country in the sale of our product. Must be an engineer who is or has been connected in a sales capacity with a company selling a product of an engineering nature. While our products are sold entirely to the electrical industry it is not essential that man we want must of necessity be connected with this industry at the present time. We are much more interested in a high grade man, who has had a broad sales experience in the sale of products of a general engineering nature. Application by letter. Headquarters, Ohio. V-3329.

MEN AVAILABLE

ELECTRICAL AND MECHANICAL SUPERVISOR. Experience; operation, maintenance, and construction, of power plants, substations, transmission and distribution systems: twelve years' practical experience, of which nine years was in foreign countries. Speaks Spanish fluently, understands Portuguese and Italian. Available for foreign or domestic service, Jan. 1st. E-4062.

ELECTRICAL ENGINEER, university technical graduate and Westinghouse test. Seven years experience on electrical construction, operation, and trouble work with substation, power house and switchboard equipment. Desires opportunity for permanent position with electric railway, public utility or consulting engineer in Middle West. Married. E-4063.

EXPERIENCED CONSTRUCTION AND MAINTENANCE SUPERINTENDENT available, age 38, married. Fourteen years' experience in construction, maintenance and operation of power plant, utility, and factory equipment. Have designed and supervised construction of steam turbine plant, and electric substations, organized and directed maintenance department operating 20,000 horse power in heating equipment, six million gallon daily pumping, filter, and sewage plant with technical control; 3000 kw. in electrical equipment, etc. Have also had charge of maintenance department in factory employing thirty six hundred. Have secured efficient operation adequately reported to a busy executive. At present employed, but desire connection in middle west where further advancement may be had. E-4064.

ELECTRICAL ENGINEER AND SWITCHBOARD SPECIALIST thoroughly familiar with automatic substation and outdoor substation equipment, six years with General Electric Company including G. E. Test, two years' additional experience in executive sales with distributor and public utility. Age thirty. Graduate of Virginia Tech., Associate A. I. E. E., American. Desires permanent position in progressive organization where experience counts. Best references. E-4065.

DRAFTSMAN, technically trained man with five years' experience on power plant and substation layouts, outdoor transformer and high-tension installations. Desires responsible position with opportunity for advancement. Location, N. Y. City. Age 27, Associate A. I. E. E. E-4066.

ELECTRICAL ENGINEER, 4 years' experience distribution engineering, at present employed desires a change. Location preferred, Middle West. E-4067.

RADIO ENGINEER, Assoc. A. I. E. E. and I. R. E., desires position with radio research or manufacturing concern in the U. S. or Canada. Six years' practical experience in development and design of commercial and experimental apparatus. Three years in Signal Corps Research, two years large electrical manufacturing company and one year in wholesale selling and private experimentation. Graduate E. E. and has technical knowledge of French and German. Thoroughly experienced in the design of broadcasting transmitters and receivers, as well as all radio measurement. Excellent knowledge of radio patent situation in U. S. and Canada. Age 27, married. Available at once. E-4068.

ELECTRICAL ENGINEER, age 25, single. Three years mechanical and electrical drafting. Desires to break into field of hydroelectric development. Will also consider production and sales engineering. Any location in U. S. Available at once. Associate A. I. E. E. Residence, Brooklyn, N. Y. E-4069.

ELECTRICAL ENGINEER experienced in design of switchboards and relay protection wants position with opportunities for future. Thorough knowledge of transmission lines. E-4070.

ELECTROCHEMIST, gets practical results. Numerous practical patents. Lately developed original methods for sealing metal to glass. Experience in low and high tension. Nothing under $500 a month considered. Open to part time contract for research on own premises. E-4071.

SUPERINTENDENT OF HYDROELECTRIC SYSTEM wishes to make a change, has had wide and varied experience on construction as well as operation, also a technical training, associate member of the A. I. E. E. and I. E. C. Can furnish best of references. New England States or Eastern Canada preferred. E-4072.

SALES ENGINEER, Associate A. I. E. E., desires a position as sales manager or assistant. Have had practical experience electrical contracting, telephone construction and office detail, now finishing seventh year as jobbers salesman selling central stations and retail dealers motors, meters, transformers and general supplies. E-4073.

RESEARCH ASSISTANT. Age 28. Graduate in electrical engineering and industrial chemistry. Experience covers practical and theoretical work in radio, physics and electrical testing and design with government, college and industrial laboratories. Would consider position as research assistant, instructor or assistant to consulting engineer. E-4074.

ELECTRICAL ENGINEER, age 27, technical education, 8 years' experience contracting, testing, and construction. Last 4 years with electrical construction company in executive capacity in connection with substation construction. Would prefer entering sales organization of electrical manufacturing concern. E-4075.

ELECTRICAL DESIGNING ENGINEER, graduate, age 30, married. Four years on design of hydroelectric generating and transformer stations. Two years construction work and two years in factory on production work. Experienced in handling draftsman and other help. Desires position as chief draftsman or designing engineer. Excellent references. E-4076.

RADIO ENGINEER, Member A. I. E. E., desires permanent connection radio research on manufacturing concern. Eleven years' radio experience, one year with research laboratory of one of the largest electrical companies in U. S. A. Graduate in Europe. Thorough knowledgo of

manufacturing of thermionic tubes. Recently engaged in developing various radio apparatus. Age 34. Married. E-4077.

GENERAL SUPERINTENDENT or OPERATING ENGINEER,—Interurban railway. Have had charge of railway property, also supervision of large construction programs with power companies—plant and transmission. A number of years experience as assistant to Superintendent in charge of d-c. and a-c. substations. Some technical training. Age 34, married, member of A. I. E. E. At present employed. Available in one month. E-4078.

ELECTRICAL ENGINEER, technical graduate, 16 years' experience, 6 years' with G. E. Co. test and engineering, 10 years' with large high-voltage hydroelectric systems both engineering and operation of which four years was spent in Mexico, speaks Spanish, at present employed, seeks position as electrical engineer in North or South America. Married. E-4079.

ELECTRICAL ENGINEER, Iowa State College, four years' experience in General Electric Co. test, Schenectady, fifteen years' experience in supervision of steam power plants, for a trolley system. Understands combustion, design, and construction. Desires position as executive in connection with the power service for utilities or manufacturing concern. Can give good references. E-4080.

ELECTRICAL SUPERINTENDENT, with twenty-two years' practical experience} sixteen years' executive on location, design, construction and operation electric railway and power properties, desires connection leading to permanent position. Natural ability for organization and working men to best advantage. Forty years of age, married. Available now. E-4081.

EXECUTIVE—ELECTRICAL ENGINEER, 37, with 17 years' experience in design, construction and operation of power and substations, industrial buildings, transmission systems, radio stations, electrolysis surveys, handling scientific research problems, in connection with electromagnetical apparatus, illumination and dielectrics, appraisals of plants and handling costs and operating characteristics of electrical and mechanical apparatus. Unquestionable references furnished. Member A. I. E. E., I. R. E., I. E. S. Salary $5000. E-4082.

MECHANICAL AND POWER ENGINEER, technical graduate, B. S., M. E., 8 years' broad experience, machine shop, metallurgy, sugar engineering, industrial and power plant practise, operation, design, layout, calculations, heat balance, utilization, distribution of steam, water, coal power, etc., investigation, research, reports. E-4083.

ELECTRICAL ENGINEER, graduate in chemical engineering and having some chemical plant experience desires permanent position with consulting chemical or electrical engineer or in chemical industry. As result of six years' intimate experience with electrical machinery is equipped to bring thorough knowledge of theory, design, and application to bear upon solution of problems requiring something above ordinary operating ability. Age 29, married, at present employed but available on reasonably short notice. E-4084.

FACTORY MANAGER, CHIEF ENGINEER or EXECUTIVE of nineteen years' business and engineering experience covering manufacturing, designing, executive and sales work; seven years' college training. Special experience on motors, controllers, cranes, hoists and domestic appliances. E-4085.

UNIVERSITY ELECTRICAL ENGINEERING GRADUATE desires sales position. Detroit vicinity preferred. Particularly fitted by practical experience to handle either radio or automotive electrical equipment. Some sales experience. Over 3 years in charge of electrical and gas engine research of Detroit concern. Reserve Signal Corps Officer. Age 27, married, available immediately. E-4086.

PRACTICAL INVESTIGATOR of manufacturing problems. Machinist, technical graduate, foreman, superintendent, manager. Permanent connection preferred. Age 42. Married. E-4087.

YOUNG ELECTRICAL ENGINEER. Broad experience all phases electric practise. Admirably trained for large industrial shops or assume full responsibility of electrical department. Ability to handle men and organize department to a successful issue. At present employed on large railroad middle West. No complaint with present employer, good reasons for desiring change. Will gladly consider appointment with large industrial concern needing the services of the advertisers ability. Have had foreign experience. Would travel foreign country if suitable contract would be made. Married, and can come well recommended. Assoc. A. I. E. E. and R. E. E. E-4088.

GRADUATE ELECTRICAL ENGINEER. Age 41, married; completed apprenticeship course with Westinghouse Electric & Mfg. Co. 18 years' experience in construction, operation and maintenance. Past 11 years chief electrician of large zinc mining and milling plant in Butte, Montana, in addition have also had charge of mechanical department for past two years. Have always handled successfully large crews of mechanics. Desire position with a future. E-4089.

STEEL MILL ELECTRICAL ENGINEER. Technical graduate, 1912. Thoroughly familiar with selection, installation, and operation of modern motor and control applications, and power generation. Desires permanent executive position with progressive steel plant or similar organization. Pittsburgh or Philadelphia districts preferred. Age 33. Married. Member A. I. & S. E. E. Assoc. A. I. E. E. At present employed. E-4090.

ELECTRICAL ENGINEER, technical training, Assoc. A. I. E. E., desires position having charge of the operation and maintenance of electrical machinery in power plants, substations or industrial plants, 12 years' experience installing, operating, maintaining, electrical equipment for electric lighting, and railway companies and industrial plants, age 33. Married, reliable, efficient, location immaterial. E-4091.

ELECTRICAL ENGINEER, 34, university graduate with twelve years' business, office, sales, engineering and executive experience will be available after Jan. 1, 1923. Particularly fitted to handle an executive position of a business nature requiring engineering experience and technical knowledge. Only a high grade opening can be considered. E-4092.

POWER DISTRIBUTION, TRANSMISSION, GENERATION. Electrical engineering teacher several years; three years with G. E. Company test. Now employed at good salary. Age 34, college man, seasoned ability. Am looking for man-size job as operating, construction or maintenance engineer and can handle it. Available 20 days. E-4093.

ELECTRICAL ENGINEER, several years with consulting engineer, desires position offering opportunity for advancement. Experienced in design of transmission lines, switching stations, power stations; previous test experience with W. E. & M. Co. Foreign commission considered. Opportunity would take precedence over salary. Available on two weeks to month notice. Associate A. I. E. E. Age 29, married. Further details if desired. E-4094.

WORKS ENGINEER. Age 32. Married. 14 years' mechanical electrical experience, power plants, industrial plants. Executive and business ability. E-4095.

INDUSTRIAL ELECTRICAL ENGINEER, Associate A. I. E. E. Technical education, married, age 35. 16 years' experience in industrial power generation, design, construction, distribution, maintenance and electric melting and annealing of non-ferrous metals. E-4096.

ELECTRICAL ENGINEER, technical graduate, thoroughly familiar with a-c. and d-c. equipment pertaining to coal mining, high-voltage power transmission and distribution, substations, design, construction, operation, testing, estimating, etc. Desires position as electrical engineer with progressive coal, power or industrial company preferably in Pennsylvania. E-4097.

PUBLIC UTILITY ENGINEER, specialist in rates, valuations, financial studies, engineering reports, statistical analysis, etc. Can qualify for responsible position with electric or railway utility, consulting engineer or management organization. Graduate Cornell, age 31, Protestant, married. E-4098.

ELECTRICAL ENGINEER, single, 27, four years' experience in plant operating and maintenance, one year in commercial engineering. Location immaterial. E-4099.

ENGINEER for testing and development of electrical and mechanical apparatus. Technical graduate with four years' experience in development and testing of electrical and mechanical apparatus, and materials, with engineering department of large manufacturing concern. Will consider opportunity with engineering or manufacturing concern. Available in two weeks. E-4100.

ELECTRICAL ENGINEER, technically educated with eighteen years' experience power plant operation construction and trouble shooting at home, at sea, and abroad wishes to connect with industrial plant or firm handling marine installations and repairs or wherever above experience can be best utilized. Married. Age 35. Available at reasonable notice. E-4101.

ELECTRICAL ENGINEER, technical graduate 1915, member Tau Beta Pi. Age 31, married. Seven years' experience with Westinghouse Elec. and Mfg. Co. and Amer. Tel. and Tel. Co., in the application, installation, and maintenance of power and telephone equipment. Limited sales and considerable minor executive experience. Location preferred, New York City. E-4102.

PLANT or ELECTRICAL ENGINEER has had charge of all such work in one of the largest automobile plants in the country. Technically trained man who has got results and is able to supervise all matters related to the design, construction, and operation of such plants. Available in 60 days. Age 38. E-4103.

INDUSTRIAL ENGINEER, graduate E. E. Experience in production engineering, planning, cost and efficiency payment systems, industrial investigations, overhead reduction. Best references. E-4104.

GENERAL MANAGER or CHIEF ENGINEER, past 18 months as general manager of 100 mile interurban also three city systems taken over from a receiver. Unlimited energy and time unable to overcome handicap. Desires to establish elsewhere in interurban or public utility field. 12 years' engineering construction, operating experience. Minimum salary $5000. E-4105.

CERTIFIED TECHNICAL PATENT EXPERT, expert patent investigator, and patent specification writer and prosecutor. Experienced lawyer, patent solicitor, technical expert, and engineer. Mem. A. I. E. E., Act. Mem. The Society American Military Engineers. Desires connection with opportunity to earn $5000 per year. E-4106.

ELECTRICAL ENGINEER or ASSISTANT, age 32, married. 9 years' experience in coal and steel corporation electrical depts. engaged in power applications incident to production. Power plant and substation operation. Design

and testing, high and low-tension transmission systems. Also engaged as power engineer of public utility. Capable of handling men. Steady worker. E-4107.

TECHNICAL GRADUATE, age 23, married. One and one-half years' electrical experience. Desires position with industrial or public service company. Location in middle west desirable, but not essential. E-4108.

ENGINEER TECHNICAL GRADUATE, Associate A. I. E. E. Experienced in the design of automotive electrical products and other small electrical products, coordinated technical and business training. Have held positions as office manager, superintendent of labor and production, assistant to president of large manufacturer of automotive parts. Desires position where past experience will be of use. Will consider traveling. Married, available January first. E-4109.

TECHNICALLY TRAINED YOUNG MAN experienced sales representative and engineer, high-tension and electrical construction equipment, seeks to represent manufacturer in the eastern States. E-4110.

SALES ENGINEERING GRADUATE, age 26, 5 years' experience design and construction substations, indoor and outdoor, transmission lines, hydro stations, etc. Would like position on sales where such experience would be of use. Location immaterial. Salary or salary and commission as arranged. E-4111.

ELECTRICIAN, 10 years' experience in electrical installations, repair and jobbing work of all kinds, good tracer and detailer on drafting work; graduate, electrical engineering, and telephone practise, American School of Correspondence. Associate A. I. E. E. Age 32, married. Desires position offering advancement along engineering lines. E-4112.

YOUNG MAN, 1921 graduate electrical engineer with knowledge of accounting wishes position which promises a future and advancement. E-4113.

ELECTRICAL ENGINEER, technical graduate, age 30, desires connection with an industrial plant or central station company. Ten years' experience along technical lines with a large central station company. Also four years' teaching experience in E. E. in evening schools. Best references can be furnished. E-4114.

PRACTICAL ELECTRICIAN, especially experienced in factory and mill installation and maintenance. Several years Chief Electrician of large auto plant. Age 28. Middle west preferred. E-4115.

DESIGNING ENGINEER, ELECTRICAL, age 30. Married. Technically trained. Experienced with General Electric and other concerns. Design of power stations, high-tension transformer and switching stations, transmission lines, automatic and remote control, heavy power applications. Other valuable experience. 12 years' permanent connection with engineering. Desires responsible position only with company needing successful, progressive engineer. E-4116.

GRADUATE with B. S. degrees in Electrical and Agricultural Engineering from prominent State University of middle west desires position with organization where this combination training would be of mutual benefit and where opportunities for advancement are limited only by applicants ability to measure up to them. Three years' teaching experience. Two years' practical experience in electrical, chemical and agricultural industries. Experience in handling men. Age 28 years, married, family. Location not first consideration. Available one month's notice. E-4117.

TECHNICAL GRADUATE. Nine years' experience in plant layout, operation, remote control application, underground, office and estimating work. Desires position with consulting engineering company, contractor, as estimator, follow-up and installation chief. Will consider sales in metropolitan district along engineering lines. E-4118.

CHIEF ELECTRICIAN OR MASTER MECHANIC. Age 41, sixteen years' general experience, technical training, speaks Spanish, capable of taking entire charge of construction and maintenance of mine mill or smelter machinery. Mexico or southwest preferred. E-4119.

YOUNG MAN, 24, single, graduate E. E. 1921, is looking for a career with some organization, and is willing to break in on some phase of testing or manufacturing work. At present employed but will be available, Feb. 1st. E-4120.

ENGINEER opening an office in Philadelphia to sell power and industrial plant equipment, with engineering service, wishes to negotiate with manufacturers or agents for such machinery, who do not have a representative in this territory. E-4121.

ENGINEERING GRADUATE, B. S. (E. E.) and (M. E.). Greek refugee, residing in Paris, desires position wherever his experience may be of value. Had charge of all electrical installations and maintenance at Robert College, Constantinople, and latterly instructor. Speaks French, English and Oriental languages. Salary secondary consideration. E-4122.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED DECEMBER 8, 1922

ADKINS, KELLER W., Fire Protection Engineer, Missouri Inspection Bureau, 501 Gloyd Bldg., Kansas City, Mo.

*ANDERSON, F. PAUL, Jr., Sales Engineer, Irvington Varnish & Insulator Co., Irvington, N. J.

ARCHER, LUTHER BUNYAN, Assistant in Electrical Engineering, Electrical Engineering Laboratory, University of Illinois, Urbana, Ill.

ATHERTON, HOWARD L., Electrical Construction Foreman, Kentucky & West Virginia Power Co., Betsy Layne, Ky.

BAILEY, EUGENE SAMUEL, Assistant Chief Operator, Consolidated Gas, Electric Light & Power Co., Baltimore; res., 117 Patapsco Ave., Dundalk, Md.

BECK, WILBUR ALHBORN, 626 N. Center St., Bethlehem, Pa.

BENDEROTH, EDISON T., Laboratory Tester, Union Electric Light & Power Company; 10th & St. Charles Sts., St. Louis, Mo.

*BOLLES, CARLETON FRANCIS, Cadet Engineer, Public Service Railway, Newark, N. J.

BOWMAN, N. FLOYD, Sales Engineer, Carbon Products Div., National Carbon Co., Inc., Cleveland, Ohio; res., Baltimore, Md.

BOYNTON, KENNETH KENASTON, Sales Engineer, International General Electric Co., Yokohama, Japan.

BROWN, G. CARLTON, Laboratory Chief, Union Gas & Electric Co., 4th & Plum Sts., Cincinnati, Ohio.

CAMPBELL, SETH ELEY, Assistant Engineer, Turbine Engineering Dept., General Electric Company, Lynn, Mass.

CARTER, JAMES ROSE, Assistant to Electrical Engineer, American Woolen Co., 245 State St., Boston; res., Andover, Mass.

CELIS, ATILIO, Manager, San Juan Office, International General Electric Co., Bouret Bldg., San Juan, Porto Rico.

CHAVANNES, ALBERT LYLE, Instructor in Electrical Engineering, E. E. Laboratory, University of Illinois, Urbana, Ill.

CUMMINS, P. RICHARD, Foreman, Repair Shop, Victor Talking Machine Co., Camden, N. J.; res., Philadelphia, Pa.

DACHNER, RICHARD H., Sales Engineer, Buzzell Electric Works, 544 Sansome St., San Francisco, Calif.

DEAN, SAMUEL WINTHROP, Student, Harvard University, Cambridge; res., 4 Eliot Road, Lexington, Mass.

DEATS, CHARLES T., Technical Employee American Tel. & Tel. Co., Erie, Pa.; res., Flemington, N. J.

DE BEAR, ALVIN COBY, Jr., Electrical Engineer, New York Transit Commission, 49 Lafayette St., New York, N. Y.; res., Roff Ave., Morsemere, N. J.

*DEMBER, DAVID, 41 Hamilton Ave., Passaic, N. J.

*DOUB, CYRUS L., General Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., Wilkinsburg, Pa.

ENFIELD, ERNEST EDWARD, Assistant Foreman, Substation Construction, Toronto-Hydro-Electric System, Toronto, Ont.

FOLEY, JAMES DANIEL, Instrument Section, Duquesne Light Company, 3708-5th Ave., Pittsburgh, Pa.

FRANK, WILLIAM H., Electric Maintenance, Submarine Boat Corp., Port Newark; res., Newark, N. J.

FRESHMAN, FRED C., Chief Draftsman, Kansas City Power & Light Co., Kansas City, Mo.

FULD, SIDNEY, Jr., Electrical Engineer, Transit Commission, 49 Lafayette St., New York, N. Y.

GENRICH, HERMAN CHARLES, Electrician, Cincinnati Traction Co., 1312 Traction Bldg., Cincinnati; res., Norwood, Ohio.

GRAFF, JAMES McNEAL, Electrical Testing Dept., Consolidated Gas, Electric Light & Power Co., Baltimore, Md.

GRANT, JOHN ALEXANDER, 25, Kent St., Kew, Victoria, Australia.

GREEFF, MAX, 334 Fourth Ave., New York, N. Y.

HARRISON, JOSEPH MARION, Chief Tester, Consolidated Gas, Electric Light & Power Co., Monument & Constitution Sts., Baltimore, Md.

HENDRY, CHARLES MANSER, Shop Foreman, Western Electric Co., West & Bethune Sts., New York; res., Brooklyn, N. Y.

*HENNINGER, G. ROSS, Engineer, Supply Engineering Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

HOLLY, HAROLD CLARK, Commercial Engineer, International General Electric Co., 23 Water St., Yokohama, Japan.

HOPKINS, ROBERT HIRAM, Engineering Dept., American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

HORNOR, HARRY H., Automotive Electrician, Paxton & Shutts, Danville, Ill.

HUGHES, DAVID MULVANE, Factory Engineer, Trenton Plant, Westinghouse Lamp Co., Trenton, N. J.

KESTER, ALLEN JAMES, Factory Representative, Radio Instrument Company of Washington, D. C.; 510 Lucy St., Akron, Ohio.

KING, MATHEW, Electrical Engineer, The Standard Textile Products Co., 320 Broadway, New York, N. Y.; res., Passaic, N. J.

LA CASSE, JOSEPH A., General Foreman, General Electric Co., Pittsfield, Mass.

MACKIN, JOHN, 3rd., Electrical Tester, Laboratory, Philadelphia Electric Co., 2301 Market St., Philadelphia, Pa.

MARSH, WALTER HORTON, Dept. of Electrical Equipment, Pittsburgh Coal Co. Library; res., Pittsburgh, Pa.

MATTHEWS, RALPH G., Assistant Electrical Engineer, Hydro-Electric Power Commission, 190 University Ave., Toronto, Ont.

McCLURKEN, RAYMOND W., Power Inspector & Tester, Western Electric Co., 210 Denkla Bldg., Philadelphia, Pa.

MEREDITH, CLIVE B., Special Student, Syracuse University, Syracuse; res., Cazenovia, N. Y.

MEYERS, FRANK PATRICK, Construction Foreman, Te Awamutu Electric Power Board, Te Awamutu, New Zealand.

MILLER, J. BRYAN, Resident Engineer, Elrod, Engineering Company, Dallas; Electra, Texas.

MOORE, CHARLES W., Instructor, Cass Technical High School, Detroit, Mich.

MOREHOUSE, H. PRESTON, Sharon, Conn.

MOSKOWITZ, ISRAEL, Electrical Contractor, 191 Madison St., New York, N. Y.

NORDHOLM, A. G., Sales Engineer, De Forest Radio Tel. & Tel. Co., Central Ave., & Franklin St., Jersey City, N.J.; res., Yonkers, N. Y.

O'NEILL, HERBERT ADDISON, Chief of Development Section, Installation Training Methods Dept., Western Electric Co., 833 W. Jackson Blvd., Chicago, Ill.

PEARSON, GEORGE HENRY Traffic Manager The Marconi Wireless Telegraph Co. of Canada, Ltd., Marconi Bldg., 11 St. Sacrament St., Montreal, Que.

PERKINS, HOWARD LEWIS, Assistant Engineer, Electric Bond & Share Co., 65 Broadway, New York, N. Y.

POWELL, GEORGE W., Erection Dept., Allis-Chalmers Mfg. Co., Milwaukee, Wis.

PRESS, ERNEST ELIJAH, Electrical Engineer, E. A. Shaw & Co., 14 Burg St., Cape Town, S. Africa.

PRICE, HEATH, Test Methods Engineer, Western Electric Co., Hawthorne Station, Chicago, Ill.

RAH, JOSEPH, Designing Engineer, G. & W. Electric Specialities Co., 7440 S. Chicago Ave., Chicago, Ill.

RIDOUT, PERCY, Engineer, with Robert L. Hailey Co., Inc., 88 Park Place, New York, N. Y.

SCUTT, GEORGE W., Superinendent of Construction, W. V. Pangborne & Co., 1927-29 W. Montgomery Ave., Philadelphia, Pa.

SMALL, WILLIAM, Assistant to Factory Engineer, Electric Storage Battery Co., Alleghany Ave. & 19th St., Philadelphia, Pa.

SMITH, FREDERICK ARTHUR, Radio Engineer, Marconi Co., Marconi Station, Glace Bay, N. S.

*SMITH, LOUIS GOLDEN, Assistant to Chief of Tests, Consolidated Gas, Electric Light & Power Co., Baltimore, Md.

*STAVOLI, FRANCISCO JAVIER, Shop Instructor & Professor of Mechanical Drawing, Escuela de Ferrocarrileros, Tacuba, D. F., Mexico.

STOLLMACK, RICHARD, Electrical Engineer' Freeman Brothers, 2 Duane St., New York; res., Brooklyn, N. Y.

STORRS, LUCIUS SEYMOUR, President, The Connecticut Company, 129 Church St., New Haven, Conn.

STRAND, GILBERT HENNING, Electrical Construction Foreman, San Diego Consolidated Gas & Electric Co., San Diego, Calif.

STRINGFELLOW, GEORGE E., District Manager, Edison Storage Battery Co., 1419 G. St., N. W., Washington, D. C.

STRIPP, JOHN EDGAR, Electrical Engineer, Dennison Manufacturing Co., Howard St., Framingham, Mass.

THOMAS, DAVID REED, Substation Operator, Potomac Electric Power Co., Washington, D. C.

THONE, JOHN F., Instructor, Wentworth Institute, Ruggles St., Boston, Mass.

TOWNSEND, LEROY STEWART, Chief, X-Ray Laboratory, Ancon Hospital, Ancon, C. Z.

WALKER, JOHN DANIEL, Instrument Repair Man, Duquesne Light Co., 3708-5th Ave., Pittsburgh; res., Swissvale, Pa.

WASSERMAN, HARRY, Electrician, Abraham & Straus, Fulton St., Brooklyn,; res., Maspeth, N. Y.

*WOODBURY, DAVID OAKES, Engineer, The Pacific Tel. & Tel. Co., 513 Sheldon Bldg., San Francisco, Calif.

*ZIMMERMAN, CLARENCE LeROY, Investigator, Western Electric Co., Chicago, Ill.

Total 77

*Formerly Enrolled Students

ASSOCIATE REELECTED DECEMBER 8, 1922

BARNARD, ROBERT BOWER, Electrical Draftsman, Skagit River Development, City of Seattle, 1400 Alaska Bldg., Seattle, Wash.

MEMBERS ELECTED DECEMBER 8, 1922

DUNSHEATH, PERCY, Chief of Research Dept., W. T. Henley's Telegraph Works Co., Ltd., North Woolwich, London, E. 16, Eng.

FRENCH, JOSEPH ALLEN, Electrical Engineer, Eastern Connecticut Power Co., 362 Main St., Norwich, Conn.

MILLIKAN, ROBERT ANDREWS, Director Norman Bridge Laboratory of Physics, California Institute of Technology, Pasadena, Calif.

NYSWANDER, REUBEN E., Professor of Physics & Director of the School of Electrical Engineering, University of Denver, Denver, Colo.

MEMBER REELECTED DECEMBER 8, 1922

ROWE, GEORGE HERBERT, Engineer, California Railroad Commission, 806 Pacific Finance Bldg., Los Angeles, Calif.

MEMBER REINSTATED DECEMBER 8, 1922

KRIBS, GORDON, Electrical Engineer, New Brunswick Electric Power Commission, St. John, N. B.

FELLOW ELECTED DECEMBER 8, 1922

MAZEN, NATALIS, Honorary Director of the Railways of the State of France, 7 rue Henri Martin, Paris XVI, France.

TRANSFERRED TO GRADE OF FELLOW DECEMBER 8, 1922

MITCHELL, WILLIAM E., Assistant General Manager, Alabama Power Co., Birmingham, Ala.

TRANSFERRED TO GRADE OF MEMBER DECEMBER 8, 1922

BLAISDELL, LEONARD T., Local Manager, General Electric Co., Washington, D. C.

CARLTON, H. E., Chief Electrical Engineer, Virginia Iron, Coal & Coke Co., Toms Creek, Va.

COLEMAN, RAYMOND M., Manager, Electrical Department, Fairbanks Morse & Co., New York, N. Y.

GURDES, FRED A., Electrical Layout Engineer, with C. H. Shepherd, Chicago, Ill.

LINCOLN, E. S., President, E. S. Lincoln, Inc., Portland, Me.

OBERMAIER, JOHN A., Engineer in Charge, Illinois Testing Laboratories, Inc., Chicago, Ill.

RANSOM, LEWIS L., Vice-President & Treasurer, Ransom & Anderson Co., Inc., Jersey City, N. J.

STEINBACH, EDWARD S., Mechanical Engineer, Stone & Webster, Inc., Boston, Mass.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held December 4, 1922, recommended the following members of the Institute for transfer to the grades of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

PECK, BERT H., General Manager, Southern Illinois Light & Power Co., St. Louis, Mo.

To Grade of Member

BERN, EMIL G., Switchboard Engineer, General Electric Co., Schenectady, N. Y.

BOWDITCH, ROY, Electrical Engineer, West Virginia Engineering Co., Norton, Va.

MURNAN, J. A., Electrical Superintendent, Motive Power Dept., Interborough Rapid Transit Co., New York, N. Y.

WOLF, H. CARL, Chief Engineer, Public Service Commission of Maryland, Baltimore, Md.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before January 31, 1923.

Alfery, Henry., F. Milwaukee, Wis.
Allen, C. Edward, Seattle, Wash.
Allen, David, Syracuse, N. Y.
Allen, Lawrence H., New York, N. Y.
Allan, Walter R., St. Louis, Mo.

Anderson, John W., 3rd, Philadelphia, Pa.
Angel, Harry H., Sparrows Point, Md.
Baber, James E., Galesburg, Ill.
Ballard, John A., Madison, Wis.
Baltzer, John B., St. Louis, Mo.
Bangs, Harold H., Hendersonville, N. C.
Banthin, John F., Bridgeport, Conn.
Baxter, Ralph H., St. Louis, Mo.
Becker, Matthew M., New York, N. Y.
Bentley, Albert N., San Joaquin, Cal.
Bergh, Fredrik G., Mexico, D. F., Mex.
Berry, Earle A., New Orleans, La.
Bespalow, Jack A., New York, N. Y.
Best, K. H., Chicago Heights, Ill.
Beyer, Claude F., Ft. Wayne, Ind.
Biggert, Edward F., Cleveland, Ohio
Boden, William H., Springfield, Mass.
Bowler, Frank I., Poughkeepsie, N. Y.
Bowman, Philip G., Pittsfield, Mass.
Bradfield, Paul E., Los Angeles, Cal.
Braestrup, Carl B., New York, N. Y.
Brant, Bronson, Detroit, Mich.
Brennecke, Robert A., New York, N. Y.
Brokaw, Charles, Schenectady, N. Y.
Brooks, Bernard W., Staten Island, N. Y.
Brown, Earle McK., Oakland, Cal.
Brown Harry F., New Haven, Conn.
Brown, J. Stanley, New Orleans, La.
Burkhart, George J., Milwaukee, Wis.
Burtnett, Robert M., New York, N. Y.
Burton, Thomas J., Washington, D. C.
Cahall, Fred B., Pittsfield, Mass.
Cahill, Walter J., Troy, N. Y.
Calame, Carroll E., Stillwater, Okla.
Carney, John V., Brooklyn, N. Y.
Carpenter, Charles B., Stanford University, Cal.
Carswell, Robert McC., Brookline, Mass.
Case, Henry R., Pasadena, Cal.
Cattell, Gilbert W., Mare Island, Cal.
Chapin, Carl K., (Member), Los Angeles, Cal.
Chen, Li, Schenectady, N. Y.
Clayton, Lawrence L., Cambridge, Mass.
Conroy, Joseph M., Montreal, Que.
Cooley, Gilbert, St. Paul, Minn.
Cotter, James L., Jr., St. Louis, Mo.
Crapo, Charles A., (Member), Denver, Colo.
Crow, Osler G., Mullins, W. Va.
Dannebaum, Otto, Los Angeles, Cal.
Dater, A. W., Stamford, Conn.
Davidson, Ross W., New York, N. Y.
Deering, John J., (Member), Norton, Va.
Defandorf, Francis M., Washington, D. C.
Dicianne, Leo J., St. Louis, Mo.
Dickey, Clifford E., St. Louis, Mo.
Dickey, Robert W., (Member), Lexington, Va.
Dolch, Bruce E., St. Louis, Mo.
Domingues, Francis J., Boston, Mass.
Doukas, Samuel J., Portland, Ore.
Dressler, Carl A., College Point, L. I., N. Y.
Driy, John A., St. Louis, Mo.
Dunbar, John R., Cambridge, Mass.
Dunlap, Robert L., Philadelphia, Pa.
Defandorf, Francis M., Washington, D. C.
Eastman, Walter L., Cleveland, Ohio
Edsall, Robert G., E. Pittsburgh, Pa.
Edwards, Paul G., Columbus, Ohio
Eide, Randolph, Cleveland, Ohio
Eisele, Herman J., Chicago, Ill.
Epstein, Monroe, E. Pittsburgh, Pa.
Fairchild, F. Earle, Phoenixville, Pa.
Fenstermacher, Walton S., St. Louis, Mo.
Fisher, Raymond C., San Francisco, Cal.
Fleming, Erwin, Pittsburgh, Pa.
Fletcher, Harvey, (Member), New York, N. Y.
Foreman, William T., Chicago, Ill.
Forster, William D., Philadelphia, Pa.
Foster, Ronald M., New York, N. Y.
Fritz, Harry R., St. Louis, Mo.
Gaige, Lisle E., New York, N. Y.
Galizia, John D., Brooklyn, N. Y.
Garman, Charles P., Los Angeles, Cal.
Gathright, W. E., Atlanta, Ga.
Goddard, Myron, C., New York, N. Y.
Goss, Harold R., Mansfield, Ohio
Gray, Samuel McK., New York, N. Y.
Gunderson, N. E., St. Louis, Mo.
Guy Robert R., E. Pittsburgh, Pa.
Hart, Roland I., Collingswood, N. J.
Harvey, Herbert A., Los Angeles, Cal.
Haugh, Henry A., Jr. New Haven, Conn.
Hayden, Henry T., Jr., Tacoma, Wash.
Hayford, Benjamin I., E. Pittsburgh, Pa.
Haynen, Joseph R., New Orleans, La.
Heim, Richard M., Cincinnati, Ohio
Herf, Rex A., Napa, Cal.
Herkner, Clarence G., San Diego, Cal.
Hertzberg, Harry ,(Member), New York, N. Y.
Hibbard, Lloyd J., (Member), E. Pittsburgh, Pa.
Hicks, Thomas R., Philadelphia, Pa.
Hill, Allan W., Pittsburgh, Pa.
Hillhouse, Albert S., Columbus, Ohio
Hirth, Anders, Mt. Vernon, N. Y.
Hitner, George W., James City, Pa.
Hoffman, Edwin S., E. Pittsburgh, Pa.
Hollister, George E., Schenectady, N. Y.
Holst, Leif, New York, N. Y.
Howdon, Herbert J., Antioch, Cal.
Hudak, John L., Jr., Kenmore, Ohio
Huggins, Burton, Schenectady, N. Y.
Hume, Samuel E., Newark, N. J.
Hurlbert, James D., Gorgas, Ala.
Hurst, Harry M., Pittsburgh, Pa.
Huston, Marshall N., St. Louis, Mo.
Jenkins, Charles F., Wilkinsburg, Pa.
Jenkins, Millard C., St. Louis, Mo.
Jepson, Mark B., Pittsburgh, Pa.
Johnson, Edward L., Brooklyn, N. Y.
Johnston, Richard J., Washington, D. C.
Keen, Royal F., Ft. Wayne, Ind.
Keller, William A., Pittsburgh, Pa.
Kessel, Herbert, Indianapolis, Ind.
King, Robert W., (Member), New York, N. Y.
Klein, Alexander, New York, N. Y.
Kline, C. Howard, Pittsfield, Mass.
Klopp, Norman F., Cincinnati, Ohio
Knuth, Harry G., Rochester, N. Y.
Koenig, William J., St Louis, Mo.
Lallier, Wesley C., Milwaukee, Wis.
Lamberton, Hugh D., Vancouver, B. C.
Lane, R. H., St. Louis, Mo.
Lange, Edward H., Annapolis, Md.
Lawson, Ralph H., New York, N. Y.
Legler, Edward V., Schenectady, N. Y.
Lewis, John E., Milwaukee, Wis.
Liddle, Ralph W., Chicago,Ill.
Little, Douglas H., Westmont, N. J.
Little, J. Herman, San Francisco, Cal.
Lubert, Charles G., Brooklyn, N. Y.
Luft, Ernest W., Rockport, Wash.
Lunge, George S., Schenectady, N. Y.
Lynch, William W., E. Pittsburgh, Pa.
Lyng, John J., (Member), New York, N. Y.
Magee, James C., Hastings-on-Hudson, N. Y.
Mahon, Walter, Yonkers, N. Y.
Maitland, Thomas J., W. Philadelphia, Pa.
Male, Arthur N., Los Angeles, Cal.
Martinez-Carranza, Lauro, Monterrey, N. L. Mex.
Martz, Guy E., Phoenix, Ariz.
Matthews, Alfred H., Williamson, W. Va.
Maxfield, Joseph P., New York, N. Y.
McCann, John P., Worcester, Mass.
McGeehan, William L., Wheeling, W. Va.
McLarn, Ernst S., New York, N. Y.
Menut, Leroy E., New York, N. Y.
Miller, Glenn, B., Baltimore, Md.
Miller, Henry R., Philadelphia, Pa.
Miller, Kenneth W , Rockport, Wash.
Missimer, Carrol, Philadelphia, Pa.
Moese, Richard C., Chicago, Ill.
Mohr, Frank C., Cleveland, Ohio
Moles, Frank C., Cleveland, Ohio
Molskness, Nels S., Colman, S. Dakota
Moore, Paul, Fresno, Cal.
Morgan, Harry R., Seattle, Wash.
Morrill, Ethelbert, B. San Francisco, Cal.
Morris, Earle H., Bismark, N. Dakota
Morrow, Earl R., Springfield, Ohio
Naudain, Willis A., Wilmington, Del.
Nelson, Cyril B., San Francisco, Cal.
Newton, William E., Stockton, Cal.
Oberlander, Felix R., (Member), Salt Lake City, Utah
O'Donnell, Joseph J., Rochester, N. Y.
O'Malley, Thomas P., Los Angeles, Cal.
Osterman, William, Philadelphia, Pa.
Paige, Andrew F., Springfield, Mass.
Parry, Charles E., St. Louis, Mo.
Parsons, Richard J., E. Pittsburgh, Pa.
Patrick, Charles E., St. Louis, Mo.
Patterson, James R., Pittsfield, Mass.
Peterson, William S., Los Angeles, Cal.
Petke, Eugene J., New York, N. Y.
Pittman, Ralph R., Pine Bluff, Ark.
Plumb, Harry J., Jackson, Mich.
Pool, Alfred D., St. Louis, Mo.
Porter, Frederick M., Easton, Pa.
Porter, Russell W., Boulder, Colo.
Portnell, James R., (Member), St. Louis, Mo.
Preston, Ray W., Los Angeles, Calif.
Price, Clarence R., Milwaukee, Wis.
Price, Karl D., Columbus, Ohio
Price, Percy A., Cleveland, Ohio
Priest, Charles L., New York, N. Y.
Pusey, Parker E., New York, N. Y.
Quarles, Donald A., New York, N. Y.
Rathmer, Felix M., Youngstown, Ohio
Renshaw, Richard A., New York, N. Y.
Rimmey, John F., Washington, D. C.
Roberts, Lowden S., St. Louis, Mo.
Rodgers, James A., St. Louis, Mo.
Role, Maurice H., Roxbury, Mass.
Roman, E. L., Wilkinsburg, Pa.
Russo, Julio, Brooklyn, N. Y.
Sandwell, Lionel H. B., (Member), Schenectady, N. Y.
Schenck, Le Roy, Maplewood, N. J.
Schmich, John E., Bethlehem, Pa.
Schneider, Carl L., New York, N. Y.
Schneider, Walter G., Cleveland, Ohio
Schnure, Fred O., (Member), Sparrows Point, Md.
Scott, James P., St. Louis, Mo.
Scott, L. Wilson, Charleston, W. Va.
Schaffer, Ralph L., Akron, Ohio
Shapiro, Leo, St. Louis, Mo.
Shaw, Alfred E., Boston, Mass.
Shepherd, Henry A., Trail, B. C.
Shinkle, Jay B., Milwaukee, Wis.
Shouse, John F., St. Louis, Mo.
Sicher, Jake, Los Angeles, Calif.
Siewert, Herbert P., Alexandria, Va.
Simons, Mayrant, Syracuse, N. Y.
Skillman, John M., New York, N. Y.
Slade, Frank L., Chicago, Ill.
Slocum, Chester C., New York, N. Y.
Smart, Willard R., Los Angeles, Calif.
Smith, Irving R., E. Pittsburgh, Pa.
Smith, Thomas D., Chicago, Ill.
Smith, Walter, Wenatchee, Wash.
Smith, Walter L., Los Angeles, Calif.
Snider, Howard N., Milwaukee, Wis.
Somerville, Thomas D., E. Pittsburgh, Pa.
Sorenson, Helmer, Milwaukee, Wis.
Stamper, Hamilton A., Brooklyn, N. Y.
Stathas, P. P., Milwaukee, Wis.
Stewart, Charles C., Toronto, Ont.
Strom, Albert P., Lafayette, Ind.
Stumpf, Walter, Towson, Md.
Sudzuki, Tsunezo Z., New York, N. Y.
Sully, Robert B., Schenectady, N. Y.
Summers, Guy M., Rochester, N. Y.
Svitavsky, Robert I., Milwaukee, Wis.
Sydnon, Claude S., (Member), S. Richmond, Va.
Symes, Alfred N., Cleveland, Ohio
Symonds, Clarence Morton, Washington, D. C.
Tenney, Harry W., E. Pittsburgh, Pa.
Terman, Frederick E., Boston, Mass.
Terrill, Stewart R., Newark, N. J.
Thomas, Albert G., Lynchburg, Va.
Thompson, Elmer O., New York, N. Y.
Tillotson, Noyes D., Schenectady, N. Y.
Toensfeldt, Ralf T., (Member), St. Louis, Mo.
Turner, Edmund T., Brooklyn, N. Y.
Tyler, Charles L., Hazelton, Pa.
Uhl, Frederick, Cleveland, O.
VanHook, Errett, (Member), Atlanta, Ga.
Veverka, Frank, New York, N. Y.
Voelker, Walter R., (Member), New York, N. Y.
Voight, Edward A., Brooklyn, N. Y.
Walker, Cedric J., Brattleboro, Vt.
Waters, Barrett, Cincinnati, Ohio
Weingartner, Charles R., Philadelphia, Pa.

Wenty, Oliver H., Los Angeles, Calif.
Whisler, George M., Derry, Pa.
Wilder, Robert F., Dover, N. H.
Williams, Arthur L., Los Angeles, Calif.
Williamson, Bert A., (Member), Los Angeles, Calif.
Wilson, Archibald F., Cleveland, Ohio
Wilt, Melvin C., Cleveland, Ohio
Wisner, Raymond R., Boston, Mass.
Witherell, Harrison C., (Member), Abington, Mass.
Wollam, Gerald Z., Berkeley, Calif.
Woodmansee, Walter L., Worcester, Mass.
Woods, Arthur J., Boston, Mass.
Wyche, Philip L., Denver, Colo.
Young, W. Forrest, Pittsburgh, Pa.
Zahm, Joseph J., New York, N. Y.

Total 279

Foreign

Cross, Harry (Member), Auckland, N. Z.
Damania, Behramji, (Member), Dharavi, Bombay, India
Higashijima, Kozo, Osaka, Japan
Valldejuly, Ramon R., San Juan, P. R.
Vandevort, John H., Balboa, C. Z.
Richardson, Jocelyn A. St. C., Surbiton, Eng.

Total 6

STUDENTS ENROLLED DECEMBER 8, 1922

15795 Ducote, Charles H., Massachusetts Institute of Technology
15796 Martin, John I., School of Engineering of Milwaukee
15797 Peacock, Harold I., School of Engineering of Milwaukee
15798 Hayes, Glenn O., School of Engineering of Milwaukee
15799 Miller, Ralph I., School of Engineering of Milwaukee
15800 Matsumoto, Robert Y., School of Engineering of Milwaukee
15801 Knorr, Wilbur, School of Engineering of Milwaukee
15802 Davis, John I., School of Engineering of Milwaukee
15803 Lovering, Paul W., School of Engineering of Milwaukee
15804 Waterstraut, Lloyd C., School of Engineering of Milwaukee
15805 Ihrke, Elmer A., School of Engineering of Milwaukee
15806 Miers, A. M., School of Engineering of Milwaukee
15807 Tolbert, Bryce W., School of Engineering of Milwaukee
15808 Bert, Alejandro F., School of Engineering of Milwaukee
15809 Greeson, George A. Jr., School of Engineering of Milwaukee
15810 Ebert, Karl R., School of Engineering of Milwaukee
15811 Hutchinson, William D., School of Engineering of Milwaukee
15812 Cole, Claude, School of Engineering of Milwaukee
15813 Lea, Garrett R., School of Engineering of Milwaukee
15814 Neblung, Erwin, School of Engineering of Milwaukee
15815 Williams, Albert J., Jr., Swarthmore College
15816 Oliver, Thomas S., Swarthmore College
15817 Green, Edward A., Swarthmore College
15818 Stockton, Harold M., Oklahoma Agricultural & Mechanical College
15819 Rile, W. S., Pennsylvania State College
15820 Miller, Harold, University of Maryland
15821 Monosmith, M. Glenn, Oregon State Agricultural College
15822 Slater, Francis R., Oregon State Agricultural College
15823 Lovegren, Calvert A., Oregon State Agricultural College
15824 Ayres, Edmund D., Massachusetts Institute of Technology
15825 Horowitz, Saul, New York Electrical School
15826 Sprinkle, Golie B., Bliss Electrical School
15827 Arnold, Oscar P., Marquette University
15828 Brugger, Karl Anthony, Marquette University
15829 Cordes, Edwin L., Marquette University
15830 Hoffmann, Norbert W., Marquette University
15831 Sywulka, Victor S., Marquette University
15832 Steinicka, Raymond F., Marquette University
15833 Kreciszewski, Alex. A., Marquette University
15834 Henre, Merle R., Kansas State Agricultural College
15835 Peterson, Elton D., Virginia Military Institute
15836 Moog, George C., Brooklyn Polytechnic Institute
15837 Harrington, Cornelius E., Massachusetts Institute of Technology
15838 Travers, Fred H., Massachusetts Institute of Technology
15839 Macgillivray, Malcolm S., Queen's University
15840 Collyer, Ernest, Queen's University
15841 Allen, John D., Pratt Institute
15842 Anderson, Robert V., Jr., Pratt Institute
15843 Handwerg, William, Pratt Institute
15844 Bergman, Harry J., Pratt Institute
15845 Brown, Everett H., Pratt Institute
15846 Peterson, John A., Pratt Institute
15847 Brown, John L., Pratt Institute
15848 Meyer, Herman W., Pratt Institute
15849 Bristol, Franklin B., Pratt Institute
15850 Leavitt, Ronald B., Pratt Institute
15851 Anderson, George O., Pratt Institute
15852 Wild, James H., Pratt Institute
15853 Walker, Harry N., Pratt Institute
15854 Houck, Harold E., Pratt Institute
15855 Guenther, William C., Pratt Institute
15856 Carpenter, Harold S., Pratt Institute
15857 Calhoun, Henry M., Pratt Institute
15858 Steinbuehler, Edward A., Pratt Institute
15859 Belin, Herbert A., Pratt Institute
15860 Weber, Henry A., Pratt Institute
15861 Earsy, Henry A., Pratt Institute
15862 Melbourne, Floyd F., Pratt Institute
15863 Meder, Francis B., Pratt Institute
15864 Greene, Samuel R., Pratt Institute
15865 Muir, Andrew C., Carnegie Institute of Technology
15866 Weeks, John R., Bliss Electrical School
15867 Schnautz, William J., Tri-State College of Engineering
15868 Feaster, Wilbur C., Johns Hopkins University
15869 Batt, Lewis T., Massachusetts Institute of Technology
15870 Hamburger, Ferdinand, Jr., Johns Hopkins University
15871 Montgomery, Douglas, Massachusetts Institute of Technology
15872 Nowell, Keith, Kansas State Agricultural College
15873 Norrie, Le Roy W., Kansas State Agricultural College
15874 Thomasson, N. R., Kansas State Agricultural College
15875 Spring, Glenn W., Kansas State Agricultural College
15876 Teall, Harley A., Kansas State Agricultural College
15877 Weckel, George H., Kansas State Agricultural College
15878 Fulhage, O. F., Kansas State Agricultural College
15879 Johnson, D. Ronald, University of Colorado
15880 Crow, Ralph L., University of Colorado
15881 Lenning, George, University of Colorado
15882 Caywood, Russell E., University of Colorado
15883 Palmer, Harlan B., University of Colorado
15884 Arnold, Otto B., University of Colorado
15885 Stone, C. Arthur, University of Colorado
15886 Downey, Kenneth R., University of Colorado
15887 Fabrizio, Ernest N., University of Colorado
15888 Merrill, Marcellus S., University of Colorado
15889 Anderson, Carl O., University of Colorado
15890 Keller, Charles W., University of Colorado
15891 Leaming, Hugh M., University of Colorado
15892 Hidy, John W., University of Colorado
15893 McKinley, John L., University of Colorado
15894 Richardson, Henry M., University of Colorado
15895 McWha, Robert D., University of Colorado
15896 Hoxie, Louis C., University of Colorado
15897 Clifford, Charles J., University of Colorado
15898 Schnell, Louis J., University of Colorado
15899 Toomey, Paul A., University of Colorado
15900 Danni, Anton, J., University of Colorado
15901 Owen, Robert H., University of Colorado
15902 Oldenburg, Paul R., University of Colorado
15903 Blake, Frank J., University of Colorado
15904 Martelon, Fred U., University of Colorado
15905 McNutt, William H., University of Colorado
15906 Dewey, Vlen H., University of Colorado
15907 Helms, Charles D., Brooklyn Polytechnic Institute
15908 Cohen, Moritz A., University of Virginia
15909 Bronner, Charles H., Johns Hopkins University
15910 Walters, Norman F., Johns Hopkins University
15911 Singer, Solomon, Yale University
15912 Andrews, Rufus A., Yale University
15913 Fox, Florian J., Yale University
15914 Sundius, Herbert, Yale University
15915 Griffin, Franklin J., Mass. Institute of Technology
15916 Rogahn, Leonard A., Tri-State College of Engineering
15917 Hill, Floyd H., Tri-State College of Engineering
15918 Lofstrom, Jonas W., Tri-State College of Engineering
15919 Hill, George J., Johns Hopkins University
15920 Parry, Grant W., Lafayette College
15921 Hartman, Cyril J., University of Notre Dame
15922 Brown, Vincent J., University of Notre Dame
15923 Vient, Louis F., Rhode Island State College
15924 Stouch, Charles R., Johns Hopkins University
15925 Black, C. Howard, Johns Hopkins University
15926 Welch, Robert C., Pennsylvania State College
15927 Dickinson, Albert G., McGill University
15928 Patton, Gordon S., University of Maryland
15929 Taubert, Herman E., South Dakota State School of Mines
15930 Tyrrell, Harvey L., South Dakota State School of Mines
15931 Fredrichsen, Arne, South Dakota State School of Mines
15932 Engstrand, Waldo A., Northeastern University
15933 Sydnor, George W., Virginia Military Institute
15934 Kezar, George L., McGill University
15935 Williams, Aurelius, New York Electrical School
15936 Webb, John L., University of Delaware
15937 Long, G. Allison, Jr., Johns Hopkins University
15938 Roake, Roger G., Cooper Union
15939 Kahn, Joseph, Cooper Union
15940 Rothschild, Max, Cooper Union
15941 Palley, Abraham, Cooper Union
15942 Troy, John R., Cooper Union
15943 Mullee, Raymond, Cooper Union
15944 Schmidt, Harry, Cooper Union
15945 White, James L., Cooper Union
15946 Clark, Fred K., Cooper Union
15947 Critchley, William Albert, Cooper Union
15948 Harrington, Patrick J., Cooper Union
15949 Jackson, George J., Cooper Union

15950 Gathy, Stephen W., Cooper Union
15951 Brown, Charles, Cooper Union
15952 Gemmelli, John J., Cooper Union
15953 Goldman, Peter, Cooper Union
15954 Burkhart, William G., Lewis Institute
15955 Lucas, Joseph J., Lewis Institute
15956 Sowinski, Joseph P., Lewis Institute
15957 Willoughby, Harry, Jr., Lewis Institute
15958 Anderson, Oscar, Lewis Institute
15959 Hirsh, Morris, Lewis Institute
15960 Harms, Verne E., Lewis Institute
15961 Reuter, Robert B., Lewis Institute
15962 Giles, Arthur G., Lewis Institute
15963 Stoehr, Alfred O., Lewis Institute
15964 Baranov, Ralph J., Lewis Institute
15965 Smith, George R., University of California
15966 Best, Nelson L., University of California
15967 Binney, John O., University of California
15968 Brown, Henry F., University of California
15969 Cauthen, William C., University of California
15970 Copsey, Evan R., University of California
15971 Cozzo, Sam E., University of California
15972 Currier, Chas. R., University of California
15973 Dodds, Laurence B., University of California
15974 Edgar, Paul W., University of California
15975 Epstein, Sidney B., University of California
15976 Hemphill, Lawrence F., University of California
15977 Martin, Bruce W., University of California
15978 Perry, Charles W., University of California
15979 Rianda, Fred A., University of California
15980 Rosenberg, Benjamin, University of California
15981 Rule, John S., University of California
15982 Scarfe, Stanley W., University of California
15983 Smith, Harry H., University of California
15984 Van Vlear, Verne W., University of California
15985 Wissman, Joseph T., University of California
15986 Yager, Carlton L., University of California
15987 Hogle, Carl R., Carnegie Institute of Technology
15988 Jones, Vernon C., Queens University
15989 Hamilton, William R., Carnegie Institute of Technology
15990 Brash, Julian E., Massachusetts Institute of Technology
15991 Knopp, Otto R. H., Northeastern University
15992 Barney, Kenneth M., Northeastern University
15993 Sawtell, Raymond I., Northeastern University
15994 Keene, Burton F., Northeastern University
15995 Spaulding, Leland S., Lafayette College
15996 Holland, Carl T., Northeastern University
15997 Smith, Roland L., Massachusetts Institute of Technology
15998 Nordin, Gustaf R., Yale Sheffield Scientific School
15999 Krchmery, Joseph C., University of Pittsburgh
16000 Braun, Frank E., University of Pittsburgh
16001 Langguth, Paul O., University of Pittsburgh
16002 Young, Robert A., University of Pittsburgh
16003 Garroway, James McK., University of Pittsburgh
16004 Anthony, Royal B., University of Pittsburgh
16005 Hirsch, Joseph W., University of Pittsburgh
16006 Kleber, Jackson O., University of Pittsburgh
16007 Crandall, Leonard J., University of Pittsburgh
16008 Aalborg, Herbert K., University of Pittsburgh
16009 Hughes, Lester L., University of Pittsburgh
16010 Murphy, Ernest M., University of Pittsburgh
16011 Craig, George T., University of Pittsburgh
16012 Connell, Milton M., University of Pittsburgh
16013 Doyle, Harold K., University of Pittsburgh
16014 Walbeck, Joseph I., University of Pittsburgh
16015 McMichael, Robert N., University of Pittsburgh
16016 Beckett, Russell V., University of Pittsburgh
16017 Miller, John H., University of Pittsburgh
16018 Zehfuss, Edwin A., University of Pittsburgh
16019 Setna, Jehanguir A., University of Pittsburgh
16020 Walton, George K., University of Pittsburgh
16021 Fitch, Charles E., California Institute of Technology
16022 Mendenhall, H. E., California Institute of Technology
16023 deVeyher, Constantine, California Institute of Technology
16024 Hotchkiss, Thomas M., California Institute of Technology
16025 Hammond, Robert G., California Institute of Technology
16026 Jones, David T., California Institute of Technology
16027 Landan, Maurice, California Institute of Technology
16028 Merrill, Richard H., California Institute of Technology
16029 Gaudy, E. H., California Institute of Technology
16030 Jones, Walter B., California Institute of Technology
16031 Stearns, Charles F., California Institute of Technology
16032 Coffey, Jule H., California Institute of Technology
16033 Fowler, L. Dean, California Institute of Technology
16034 Holladay, William L., California Institute of Technology
16035 Ziegler, William H., Pratt Institute
16036 Stack, Irwin A., Pratt Institute
16037 Alrich, Edward B., Pratt Institute
16038 de Puy, Maurice J., Pratt Institute
16039 Novy, Alois J., Brooklyn Polytechnic Institute
16040 Van Lear, G. M., University of Virginia
16041 Brown, Jesse E., University of Arkansas
16042 Adams, Walter E., Brooklyn Polytechnic Institute
16043 McLaughlin, Harold A., Brooklyn Polytechnic Institute
16044 Swain, Harold H., Northeastern University
16045 Surabran, Peter H., Northeastern University
16046 Bond, Herbert, Kansas University
16047 Hill, Marvin L., Kansas University
16048 Covey, Arnold B., Kansas University
16049 Kent, Paul N., Kansas University
16050 Bernhard, Lester S., Ohio State University
16051 Crabtree, Thomas G., Ohio State University
16053 Neeb, Laurence S. C., Ohio State University
16054 Parry, Hollis, Ohio State University
16055 Patterson, Stanley LeR., Ohio State University
16056 Poling, A. Vinnedge, Ohio State University
16057 Shoemaker, Floyd K., Ohio State University
16058 Stutsman, James F., Ohio State University
16059 Winterhalter, William E., Ohio State University
16060 Wendt, Robert H., George Washington University
16061 Timm, Troy, Marquette University
16062 Beckwith, Laurence J., Marquette University
16063 Jones, Robert H., Marquette University
16064 Crabb, Francis A., Marquette University
16065 Hebard, William J., Marquette University
16066 Ruedy, Robert J., University of Illinois
16067 Linn, G. L. E., University of Delaware
16068 Buller, Francis H., McGill University
16069 McCarthy, John J., University of Vermont
16070 Campbell, Arthur H., Oregon Institute of Technology
16071 Kessler, George H., Oregon Institute of Technology
16072 Ludlow, Marion O., Oregon Institute of Technology
16073 Cooper, Oris L., Oregon Institute of Technology
16074 Weber, Venon G., Oregon Institute of Technology
16075 Michael, John J., Oregon Institute of Technology
16076 Carrigan, Chester J., Oregon Institute of Technology
16077 Rigg, William D., Oregon Institute of Technology
16078 Dillon, Henry K., Oregon Institute of Technology
16079 Ball, Birtley A., Oregon Institute of Technology
16080 Brailsford, Harrison D., University of Kentucky
16081 Grant, William H., University of Kentucky
16082 Graham, Charles D., University of Kentucky
16083 Clark, Jefferson D. Jr., University of Kentucky
16084 Clark, Robert, Jr., University of Kentucky
16085 Clare, Fulton W., University of Kentucky
16086 Ballinger, William P., University of Kentucky
16087 Baughman, Earle W., University of Kentucky
16088 Mock, Clifton O., University of Kentucky
16089 Rogers, Vene C., University of Kentucky
16090 Downing, W. T., University of Kentucky
16091 Wilkins, Jas. E., University of Kentucky
16092 Davidson, Lilburn C., University of Kentucky
16093 Arnold, Allie F., University of Kentucky
16094 Shouse, James L., University of Kentucky
16095 Bender, Henry P., New York Electrical School
16096 Bartunek, Edwin, University of Nebraska
16097 Moore, Leon F., University of North Dakota
16098 Thorleifson, Fridjon, University of North Dakota
16099 Trulson, Arthur F., University of North Dakota
16100 Haven, Albert D., University of North Dakota
16101 Shefveland, Arthur M., University of North Dakota
16102 Auck, Dale K., Ohio State University
16103 Yeftitch, Mile, University of Vermont
16104 Thompson, Wilmer S., Brooklyn Polytechnic Institute
16105 Dixon, John T., Johns Hopkins University
16106 Cregreen, Kenneth T., McGill University
16107 Clark, Franklin P., Sheffield Scientific School
16108 Day, George Warren, Northeastern University
16109 Strauss, Walter, Drexel Institute
16110 James, William H., University of Vermont
16111 Crandell, Malcolm P., Bucknell University
16112 Hissom, Paden M., Carnegie Institute of Technology
16113 Waite, Roger T., Worcester Polytechnic Institute
16114 Murray, John C., Lewis Institute
16115 Panegasser, Joseph F., Lewis Institute
16116 McGrath, Jerome J., Lewis Institute
16117 Harry, Zeb M., North Carolina State College
16118 Pakula, Lewis B., North Carolina State College

16119 Lineberry, Graydon H., North Carolina State College
16120 Norwood, Harold E., North Carolina State College
16121 Glenn, Karl B., North Carolina State College
16122 Andrews, John L., North Carolina State College
16123 Dartt, Veryl H., University of Vermont
16124 Aaron, James C., Jr., Massachusetts Institute of Technology
16125 White, Harrison G., Massachusetts Institute of Technology
16126 Daly, Harold J., Polytechnic Institute of Brooklyn
16127 Wiegand, Herman, Brooklyn Polytechnic Institute
16128 Case, Charles P., University of Vermont
16129 Benson, Thomas W., Drexel Institute
16130 Johnston, Oscar K., Toronto Central Technical School
16131 Grimwell, Paul C., George Washington University
16132 Jones, August F., Cornell University
16133 Zalesak, William A., Cornell University
16134 Kenah, Roland M., Cornell University
16135 Miller, George Wm., Cornell University
16136 Beyerl, Leigh W., Cornell University
16137 Forrest, Raymond T., Oregon Agricultural College
16138 Floyd, Roy E., Oregon Agricultural Coll.
16139 Bishop, Lionel J., Oregon Agricultural Coll.
16140 Davis, Edward L., Tri State College
16141 Brockway, Ladue M., Lafayette College
16142 Rector, Clinton, Johns Hopkins University
16143 Hodgkinson, Joseph L., Tri State College
16144 Rowe, Cecil A., University of Maine
16145 Heitkamp, Irvin H., Ohio State University
16146 Fielder, Cecil K., University of Texas
16147 Rumsey, Paul T., University of Texas
16148 Vogelsang, Lewis O., University of Texas
16149 Keen, A. H., University of Texas
16150 Moore, Clifton E., University of Texas
16151 Bissett, Eugene, University of Texas
16152 McCullough, Clifford H., University of Texas
16153 Brown, Henry O., University of Texas
16154 Faulkner, James H., University of Texas
16155 Hubby, Leon F., Northeastern University
16156 McElheny, George B., Carnegie Institute of Technology
16157 Schlichting, Edward N., Drexel Institute
16158 Miller, Harry D., Drexel Institute
16159 Lane, Henry M., Massachusetts Institute of Technology
16160 Walch, Donald E., Massachusetts Institute of Technology
16161 Dexter, Howard W., Jr., Massachusetts Institute of Technology
16162 Brown, Wilmer T., Drexel Institute
16163 Grozier, John W., Northeastern University
16164 Nourse, Benjamin C., Iowa State College
16165 Howell, Walter W., Iowa State College
16166 Gilbert, Leslie F., Iowa State College
16167 Schomberg, Harold J., Iowa State College
16168 Cutler, Byron H., Iowa State College
16169 Carlson, Martin F., Iowa State College
16170 Mortensen, Ole I., Iowa State College
16171 Wilson, Selden H., Iowa State College
16172 Sunde, Harold E., Iowa State College
16173 Levin, Aaron, University of Michigan
16174 Young, Paul N., University of Michigan
16175 Hodge, Robert W., University of Michigan
16176 Mills, Maurice A., University of Michigan
16177 Russell, Winfred W., University of Minnesota
16178 Eckberg, Curtis R., University of Minn.
16179 Anderson, Emil G., University of Minn.
16180 Miller, William J., University of Minnesota
16181 Arstad, Leonard O., University of Minn.
16182 Lewis, John G., University of Minnesota
16183 Furber, John R., University of Minnesota
16184 Frazee, Leonard M., University of Minn.
16185 Garthus, Ira B., University of Minnesota
16186 McGregor, Frazer, University of Minn.
16187 Sickel, Edw. C., University of Minnesota
16188 Johnson, G. A., University of Minnesota
16189 Miller, Archibald T., University of Minn.
16190 Kannenberg, Walter F., University of Minnesota
16191 Jacobson, Frank H., University of Minn.
16192 Newman, John M., University of Minn.
16193 Mangney, Hilding O., University of Minnesota
16194 Waligoski, Adam A., University of Minn.
16195 Myers, Frank Wm. A., Drexel Institute
16196 Grantham, Frederick W., Jr., Massachusetts Institute of Technology
16197 MacLean, Lachlan W., Massachusetts Institute of Technology
16198 Betz, Paul LeR., Johns Hopkins University
16199 Wyeth, Francis H., Massachusetts Institute of Technology
16200 Willis, Raymond T., Massachusetts Institute of Technology
16201 Shuman, Uriah S., Drexel Institute
16202 Knapp, Edward W., McGill University
16203 Mulligan, James E., University of Maine
16204 Lamb, John F., Carnegie Institute of Technology

Total 408

Officers A. I. E. E. 1922-1923

PRESIDENT.

(Term expires July 31, 1923)
FRANK B. JEWETT

JUNIOR PAST-PRESIDENTS

Term expires July 31, 1923)
A. W. BERRESFORD

(Term expires July 31, 1924)
WILLIAM McCLELLAN

VICE-PRESIDENTS

(Terms expire July 31, 1923)
N. W. STORER
C. G. ADSIT
F. W. SPRINGER
ROBERT SIBLEY
F. R. EWART

(Terms expire July 31, 1924)
G. FACCIOLI
W. I. SLICHTER
R. F. SCHUCHARDT
H. W. EALES
H. T. PLUMB

MANAGERS

Terms expire July 31, 1923)
L. E. IMLAY
F. F. FOWLE
L. F. MOREHOUSE

(Terms expire July 31, 1924)
HAROLD B. SMITH
JAMES F. LINCOLN
E. B. CRAFT

(Terms expire July 31, 1925)
R. B. WILLIAMSON
A. G. PIERCE
HARLAN A PRATT

(Terms expire July 31, 1926)
H. M. HOBART
ERNEST LUNN
G. L. KNIGHT

TREASURER / SECRETARY

(Terms expire July 31, 1923)
GEORGE A HAMILTON — F. L. HUTCHINSON

HONORARY SECRETARY

RALPH W. POPE

GENERAL COUNSEL

PARKER & AARON,
66 Broad Street, New York.

PAST-PRESIDENTS—1884-1922

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
*WILLIAM A. ANTHONY, 1890-91.
*ALEXANDER GRAHAM BELL, 1891-2.
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
*LOUIS DUNCAN, 1895-6-7.
*FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-2.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB, 1904-5.
SCHUYLER SKAATS WHEELER, 1905-6.
*SAMUEL SHELDON, 1906-7.
*HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-9.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.
PAUL M. LINCOLN, 1914-15.
JOHN J. CARTY, 1915-16.
H. W. BUCK, 1916-17.
E. W. RICE, JR., 1917-18.
COMFORT A. ADAMS, 1918-19.
CALVERT TOWNLEY, 1919-20.
A. W. BERRESFORD, 1920-21.
WILLIAM MCCLELLAN, 1921-22.

*Deceased.

LOCAL HONORARY SECRETARIES

Charles le Maistre, 28 Victoria St., London, S. W., England.
A. S. Garfield, 45 Bd. Beausejour, Paris 16 E, France.
H. P. Gibbs, Tata Sons, Ltd., Navsari Bu'lding, Fort Bombay, India.
Guido Semen a, N. 10 Via S. Radegonda, Milan, Italy.
Lawrence Birks, Public Works Department, Wellington, New Zealand.
John W. Kirkland, Box 1905, Johannesburg, South Africa.

A. I. E. E. Committees

GENERAL STANDING COMMITTEES

EXECUTIVE COMMITTEE

F. B. Jewett, Chairman, 195 Broadway, New York
A. W. Berresford, H. M. Hobart, R. F. Schuchardt,
G. A. Hamilton, L. F. Morehouse, W. I. Slichter.

FINANCE COMMITTEE

L. F. Morehouse, Chairman, 195 Broadway, New York
C. G. Adsit, G. L. Knight.

MEETINGS AND PAPERS COMMITTEE

E. E. F. Creighton, Chairman, General Electric Co., Schenectady, N. Y.
J. C. Clark, John Mills, A. G. Pierce.
L. W. W. Morrow,
Chairman of Committee on Coordination of Institute Activities.
Chairmen of Technical Committees.
Chairmen of Sections.

PUBLICATION COMMITTEE

Donald McNicol, Chairman, 132 Union Road, Roselle Park, N. J.
E. E. F. Creighton, F. L. Hutchinson, Wm. McClellan.
L. F. Morehouse,

COMMITTEE ON COORDINATION OF INSTITUTE ACTIVITIES

W. I. Slichter, Chairman, Columbia University, New York
E. E. F. Creighton, F. L. Hutchinson, Donald McNicol.
L. F. Morehouse,

BOARD OF EXAMINERS

H. H. Norris, Chairman, 192 Bellevue Ave., Upper Montclair, N. J.
Philander Betts, G. L. Knight, J. H. Morecroft,
E. H. Everit, Donald McNicol, N. L. Pollard,
Erich Hausmann, E. M. Sawtelle.

SECTIONS COMMITTEE

A. W. Berresford, Chairman, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
C. F. Harding, Vice-Chairman
John B. Fisken, H. B. Smith, J. Lloyd Wayne.
Chairmen of all Sections.

COMMITTEE ON STUDENT BRANCHES

C. F. Harding, Chairman, Purdue University, Lafayette, Ind.
A. C. Lanier, C. E. Magnusson, Harold B. Smith.
Charles F. Scott,

MEMBERSHIP COMMITTEE

R. B. Howland, Chairman, 125 E. 46th St., New York.
W. L. Amos, F. L. Kemp, H. T. Plumb,
R. L. Dodd, J. E. MacDonald, M. E. Skinner,
J. F. Dostal, G. H. Middlemiss, J. L. Woodress,
R. D. Parker.

HEADQUARTERS COMMITTEE

E. B. Craft, Chairman, 463 West St., New York.
F. L. Hutchinson, L. F. Morehouse.

LAW COMMITTEE

H. H. Barnes, Jr., Chairman, 120 Broadway, New York.
F. R. Ewart, G. E. Folk, Charles A. Terry.
P. Junkersfeld,

PUBLIC POLICY COMMITTEE

H. W. Buck, Chairman, 49 Wall Street, New York.
Gano Dunn, John W. Lieb, C. E. Skinner,
William McClellan,

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT

Schuyler S. Wheeler, Chairman, Crocker-Wheeler Co., Ampere, N. J.
C. A. Adams, G. Faccioli, George F. Sever,
A. H. Babcock, J. W. Lieb, H. S. Wynkoop.

COMMITTEE ON SAFETY CODES

H. B. Gear, Chairman, 72 West Adams St., Chicago, Ill.
H. C. Cushing, M. G. Lloyd, Farley Osgood,
J. C. Forsyth, Ernest Lunn, H. R. Sargent,
H. O. Lacount, Wills Maclachlan, A. M. Schoen,
Johnston Livingston, R. W. E. Moore, H. S. Warren.
H. N. Muller,

STANDARDS COMMITTEE

Executive Committee

Harold Pender, Chairman, University of Pennsylvania, Philadelphia, Pa.
H. S. Osborne, Secretary, 195 Broadway, New York
W. A. Del Mar, H. A. Lardner, F. D. Newbury,
H. M. Hobart, A. M. MacCutcheon, F. L. Rhodes,
G. L. Knight, J. F. Meyer, L. T. Robinson,
Chairmen of A. I. E. E. delegations on other standardizing bodies.

EDISON MEDAL COMMITTEE

Appointed by the President for term of five years.

(Term expires July 31, 1923)
Frederick Bedell, L. T. Robinson, Calvert Townley.
(Term expires July 31, 1924)
E.D.Adams, Chairman, H. H. Barnes, Jr., B. G. Lamme.
(Term expires July 31, 1925)
H. M. Byllesby, D. E. Drake, W. L. R. Emmet.
(Term expires July 31, 1926)
B. A. Behrend, John H. Finney, C. S. Ruffner.
(Term expires July 31, 1927)
Gano Dunn, F. A. Scheffler, W. R. Whitney.

Elected by the Board of Directors from its own membership for term of two years

(Term expires July 31, 1923)
A. W. Berresford, L. F. Morehouse, R. B. Williamson.
(Term expires July 31, 1924)
E. B. Craft, G. Faccioli, William McClellan.

Ex-Officio

Frank B. Jewett, President, George A. Hamilton, Treasurer,
F. L. Hutchinson, Secretary.

RESEARCH COMMITTEE

J. B. Whitehead, Chairman, Johns Hopkins University, Baltimore, Md.
B. A. Behrend, W. P. Dobson, M. G. Lloyd,
Edward Bennett, C. I. Hall, L. F. Morehouse,
F. S. Clark, L. A. Hawkins, G. W. Pierce,
E. H. Colpitts, D. C. Jackson, H. J. Ryan,
E. E. F. Creighton, A. E. Kennelly, C. H. Sharp,
W. A. Del Mar, J. R. Klumpp, C. E. Skinner.

TECHNICAL COMMITTEES

EDUCATIONAL

W. E. Wickenden, Chairman, 195 Broadway, New York.

W. C. Bauer, C. E. Magnusson, Harold B. Smith
Edward Bennett, G. H. Pfeif, W. L. Upson,
C. R. Dooley, H. W. Price, J. B. Whitehead,
Charles S. Howe, Charles F. Scott, Wm. R. Work.

ELECTRICAL MACHINERY

B. A. Behrend, Chairman, 85 Devonshire St., Boston, Mass.
A. S. McAllister, Secretary, 455 W. 153rd St., New York.

B. L. Barns, V. A. Fynn, P. M. Lincoln,
R. E. Brown, David Hall, H. P. Liversidge,
James Burke, H. U. Hart, F. D. Newbury,
N. A. Carle, H. M. Hobart, R. F. Schuchardt,
G. Faccioli, V. Karapetoff, Philip Torchio,
W. J. Foster, R. B. Williamson.

ELECTROCHEMISTRY AND ELECTROMETALLURGY

J. L. Yardley, Chairman, W. E. & M. Co., East Pittsburgh, Pa.

F. G. Clark, Carl Hering, J. A. Seede,
Saul Dushman L. E. Imlay, G. W. Vinal.

ELECTROPHYSICS

F. W. Peek, Jr., Chairman, General Electric Co., Pittsfield, Mass.

E. F. Burton, Wm. Fondiller, Chester W. Rice,
L. W. Chubb, Charles Fortescue, F. B. Silsbee,
J. C. Clark, Roy S. Glasgow, H. B. Smith,
C. P. Eldred, E. P. Hyde, J. B. Whitehead.
J. H. Morecroft,

INSTRUMENTS AND MEASUREMENTS

G. A. Sawin, Chairman, W. E. & M. Co., East Pittsburgh, Pa.

P. A. Borden, A. L. Ellis, Irving B. Smith,
H. B. Brooks, Paul MacGahan, H. C. Snook,
F. P. Cox, F. V. Magalhaes, F. W. Springer,
E. D. Doyle, H. S. Vassar.

IRON AND STEEL INDUSTRY

E. S. Jefferies, Chairman, Steel Co. of Canada, Hamilton, Ont.

F. B. Crosby, W. S. Hall, G. E. Stoltz,
Gordon Fox, E. T. Moore, N. W. Storer,
Eugene Friedlaender, D. M. Petty, Wilfred Sykes,
R. B. Gerhardt, J. D. Wright.

LIGHTING AND ILLUMINATION

G. H. Stickney, Chairman, Edison Lamp Works, G. E. Co., Harrison, N. J.

A. B. Cooper, G. C. Hall, R. C. Powell,
E. C. Crittenden, Henry Logan, Charles F. Scott,
W. T. Dempsey, A. S. McAllister, B. E. Shackelford,
F. F. Fowle, J. F. Meyer, W. M. Skiff.

MARINE

G. A. Pierce, Jr., Chairman, W. Cramp & Sons S. & E. B. Co., Philadelphia, Pa.
L. C. Brooks, Secretary, Bethlehem Shipbuilding Corp. Ltd., Quincy, Mass.

J. B. Bassett, Wm. Hetherington, Jr., I. H. Osborne,
R. A. Beekman, H. L. Hibbard, Arthur Parker,
Maxwell W. Day, J. S. Isdale, H. A. Pratt,
E. G. Gallagher, Wm. F. James, H. M. Southgate,
Com. C. S. Gillette, Com. M. A. Libbey, W. E. Thau,
H. Franklin Harvey, Jr., Com. C. S. McDowell, A. E. Waller.
W. F. Meschenmoser,

MINES

Graham Bright, Chairman, W. E. & M. Co., East Pittsburgh, Pa.

Willard C. Adams, L. C. Ilsley, D. C. McKeehan,
R. T. Andrae G. M. Kennedy, W. F. Schwedes,
C. N. Beebe, R. L. Kingsland, F. L. Stone,
M. C. Benedict, A. B. Kiser, W. A. Thomas,
H. W. Eales, C. D. Woodward.

POWER STATIONS

Nicholas Stahl, Chairman, Turks Head Building, Providence, R. I.

H. A. Barre, F. C. Hanker, D. C. McClure,
J. T. Barron, C. F. Hirshfeld, I. E. Moultrop,
A. E. Bauhan, H. A. Kidder, A. L. Penniman,
E. T. Brandon, W. H. Lawrence, F. A. Scheffler,
D. H. Braymer, H. P. Liversidge, R. F. Schuchardt,
H. W. Eales, R. B. Williamson.

PROTECTIVE DEVICES

H. R. Woodrow, Chairman, 360 Pearl Street, Brooklyn, N. Y.

G. H. Bragg, B. G. Jamieson, F. E. Ricketts,
P. H. Chase, M. G. Lloyd, D. W. Roper,
L. B. Chubbuck, A. A. Meyer, C. H. Sanderson,
F. C. Hanker, W. H. Millan, E. R. Stauffacher,
S. E. M. Henderson, A. G. Pierce, E. C. Stone,
E. A. Hester, N. L. Pollard, A. H. Sweetnam,
F. L. Hunt, John B. Taylor.

TELEGRAPHY AND TELEPHONY

O. B. Blackwell, Chairman, 195 Broadway, New York.

C. W. Burkett, H. W. Drake, Chester W. Rice,
G. A. Cellar, D. H. Gage, J. K. Roosevelt,
H. P. Charlesworth, H. Hulatt, Gen. Edgar Russell,
L. W. Chubb, F. H. Kroger, Arthur B. Smith,
E. H. Colpitts, F. J. Mayer, I. J. Thorp,
R. N. Conwell, L. F. Morehouse, F. A. Wolff,
C. E. Davies, W. O. Pennell, C. A. Wright.
F. A. Raymond,

TRANSMISSION AND DISTRIBUTION

E. B. Meyer, Chairman, 80 Park Place, Newark, N. J.

R. W. Atkinson, F. M. Farmer, C. N. Rakestraw,
A. E. Bauhan, L. M. Klauber, C. C. Robinson,
F. G. Baum, J. A. Koontz, Jr. D. W. Roper,
Wallace S. Clark, C. H. Kraft, C. E. Schwenger,
W. H. Cole, W. S. Lee, C. H. Shaw,
R. N. Conwell, G. J. Newton, Robert Sibley,
W. A. Del Mar, A. M. Perry, W. K. Vanderpoel,
L. L. Elden, G. G. Post, C. T. Wilkinson.

A. I. E. E. Representatives

ON AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, COUNCIL

A. E. Kennelly, John B. Taylor.

ON AMERICAN BUREAU OF WELDING

W. L. Merrill.

ON AMERICAN COMMITTEE ON ELECTROLYSIS

Bion J. Arnold, N. A. Carle, F. N. Waterman.

ON AMERICAN ENGINEERING COUNCIL OF THE FEDERATED AMERICAN ENGINEERING SOCIETIES

Comfort A Adams, W. A. Layman, Charles S. Ruffner,
C. G. Adsit, *William McClellan, *Charles F. Scott,
*John H. Finney, *L. F. Morehouse, C. E. Skinner,
F. L. Hutchinson, L. T. Robinson, *L. B. Stillwell,
Frank B. Jewett, Calvert Townley.
*Members of Executive Board.

ON AMERICAN ENGINEERING STANDARDS COMMITTEE

H. M. Hobart, Harold Pender, C. E. Skinner,
L. T. Robinson (Alternate)

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY

H. H. Barnes, Jr., Bancroft Gherardi, H. A. Lardner.

ON ENGINEERING FOUNDATION BOARD

Frank B. Jewett, E. W. Rice, Jr.

ON FRANCO-AMERICAN ENGINEERING COMMITTEE

A. M. Hunt, L. B. Stillwell.

ON JOHN FRITZ MEDAL BOARD OF AWARD

A. W. Berresford, John J. Carty, Frank B. Jewett,
Wm. McClellan,

ON JOSEPH A. HOLMES SAFETY ASSOCIATION

John H. Finney.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY

Edward D. Adams, F. L. Hutchinson, W. I. Slichter,
E. B. Craft, Alfred W. Kiddle.

ON NATIONAL FIRE PROTECTION ASSOCIATION, ELECTRICAL COMMITTEE

The chairman of the Institute's Committee on Safety Codes.

ON NATIONAL RESEARCH COUNCIL, ENGINEERING DIVISION

C. A. Adams, Bancroft Gherardi W. R. Whitney.

ON U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION

A. E. Kennelly, C. O. Mailloux, Clayton H. Sharp.

ON WASHINGTON AWARD, COMMISSION OF

John Price Jackson, Charles F. Scott.

U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION

C. O. Mailloux, President, 111 Fifth Ave., New York, N. Y.
D. C. Jackson, Vice-President,
[1]James Burke, Vice-President,
C. H. Sharp, Secretary, 556 E. 80th St., New York.

C. A. Adams, H. W. Fisher, Harold Pender
P. G. Agnew, [6]Gen. G. H. Harries, [6]S. G. Rhodes,
B. A. Behrend, H. M. Hobart, Charles Robbins,
J. J. Carty, A. E. Kennelly, L. T. Robinson
L. W. Chubb, B. G. Lamme, D. B. Rushmore,
[1]C. L. Collens, 2d, [5]R. A. Lundquist, C. F. Scott,
W. A. Del Mar, A. S. McAllister, C. E. Skinner,
[1]A. L. Doremus, [4]Com. C. S. McDowell, [3]Gen. George O. Squier,
Gano Dunn, W. S. Moody, S. W. Stratton,
[6]L. L. Elden, A. H. Moore, Elihu Thomson,
W. C. Fish, R. W. E. Moore, [2]C. L. Warwick,
L. F. Morehouse. R. B. Williamson,

[1]Representative of Electric Power Club.
[2]Representative of American Society for Testing Materials.
[3]Representative of War Department.
[4]Representative of Navy Department.
[5]Representative of Bureau of Foreign and Domestic Commerce.
[6]Representative of National Electric Light Association.

LIST OF SECTIONS

Name	Chairman	Secretary
Akron	S. C. Henton	A. P. Regal, Phila. Rubber Works Co., Akron, O.
Atlanta	G. K. Selden	H. N. Pye, Box 1743, Atlanta, Ga.
Baltimore	W. B. Kouwenhoven	F. T. Leilich, 550 Lexington Bldg., Baltimore, Md.
Boston	E. L. Moreland	F. S. Dellenbaugh, M. I. T., Cambridge, Mass.
Chicago	F. E. Goodnow	J. E. Kearns, General Electric Co., Monadnock Block, Chicago, Ill.
Cincinnati	A. M. Wilson	C. G. Eichelberger, Union Gas & Elec. Co., Cincinnati, O.
Cleveland	L. D. Bale	Chester L. Dows, Nela Park, Cleveland, O.
Columbus	F. C. Caldwell	F. C. Nesbitt, Huntington Bank Bldg., Columbus, O.
Connecticut	E. H. Everit	A.E. Knowlton, Dunham Laboratory, S. S. S., Yale University, New Haven, Conn.
Denver	H. B. Barnes	R. B. Bonney, 603 Wyoming Bldg., Denver, Colo.
Detroit-Ann Anbor	J. H. Cannon	E. L. Bailey, 1918 Ford Bldg., Detroit, Mich.
Erie	W. J. Seibert	M. W. Metzner, General Electric Co., Erie, Pa.
Fort Wayne	S. W. Greenland	A. B. Campbell, General Electric Co., Fort Wayne, Ind.
Indianapolis-Lafayette	D. C. Pyke	J. W. Hannon, Telephone Bldg., Indianapolis, Ind.
Ithaca	J. G. Pertsch, Jr.	Geo. F. Bason, Cornell University, Ithaca, N. Y.
Kansas City	Geo. C. Shaad	W. E. A. Nottorf, K. C. Tel. Co., Kansas City, Mo.
Lehigh Valley	D. M. Petty	H. G. Harvey, Penna. Edison Co., Easton, Pa.
Los Angeles	J. N. Kelman	E. R. Stauffacher, 700 Edison Bldg., Los Angeles, Calif.
Lynn	J. W. West	W. M. Howe, General Electric Co., West Lynn, Mass.
Madison	H. M. Crothers	R. G. Walter, 900 Gay Bldg., Madison, Wis.
Mexico	———	———
Milwaukee	G. G. Post	F. A. Kartak, Marquette University, Milwaukee, Wis.
Minnesota	Fred A. Otto	H. W. Meyer, Northern States Power Co., Minneapolis, Minn
New York	Calvert Townley	A. E. Waller, Lawrence Park, Bronxville, N. Y.
Oklahoma	F. W. Insull	A. D. Stoddard, Box 382 Bartlesville, Okla.
Panama	F. B. Coyle	M. P. Benninger, Box 174, Balboa Heights, C. Z.
Philadelphia	E. B. Tuttle	Ross B. Mateer, Philadelphia Elec. Co., 1000 Chestnut St., Philadelphia, Pa.
Pittsburgh	E. C. Stone	O. Needham, W. E. & M. Co., East Pittsburgh, Pa.
Pittsfield	W. P. White	A. C. Stevens, General Electric Co., Pittsfield, Mass.
Portland, Ore.	D. W. Proebstel	E. F. Pearson, Northwestern Electric Co., Portland, Ore.
Providence	R. W. Adams	F. N. Tompkins, Brown University, Providence, R. I.
Rochester	G. A. Scoville	E. A. Roeser, 34 N. Clinton Ave., Rochester, N. Y.
St. Louis	J. M. Chandlee	Lee S. Washington, 717 S. 12th St., St. Louis, Mo.
San Francisco	H. H. Henline	A. G. Jones, 807 Rialto Bldg., San Francisco, Calif.
Schenectady	C. M. Davis	C. W. Fick, General Electric Co., Schenectady, N. Y.
Seattle	W. D. Scott	E. S. Code, 3451 E. Marginal Way, Seattle, Wash.
Southern Virginia	———	———
Spokane	H. L. Melvin	E. R. Hannibal, 424 Hutton Bldg., Spokane, Wash.
Springfield, Mass.	W. A. Dick	J. Frank Murray, United Electric Light Co., Springfield, Mass.
Syracuse	R. D. Whitney	Elmer E. Strong, 615 City Bank Bldg., Syracuse, N. Y.
Toledo	Gilbert Southern	Max Neuber, 1257 Fernwood Ave., Toledo, O.
Toronto	S. E. M. Henderson	D. B. Fleming, Hydro-Elec. Pr. Comm., 190 University Ave., Toronto, Ont.
Urbana	H. A. Brown	E. B. Paine, University of Illinois, Urbana, Ill.
Utah	C. C. Pratt	C. R. Higson, Utah Pr. & Lt. Co., Salt Lake City, Utah
Vancouver	T. H. Crosby	F. W. MacNeill, Canadian General Elec. Co., Vancouver, B. C.
Washington, D. C.	L. T. Blaisdell	Roland Whitehurst, Elec. Storage Battery Co., 1823-33 L. St. N. W., Washington, D. C.
Worcester	F. J. Adams	Dean J. Locke, 125 Salisbury St., Worcester, Mass.

Total 47

LIST OF BRANCHES

Name and Location	Chairman	Secretary
Alabama Poly. Inst., Auburn, Ala.	K. H. Stough	J. F. Nettles
Alabama, Univ. of, University, Ala.	J. M. Lakeman	R. L. Harris
Arizona, Univ. of, Tucson, Ariz.	R. A. Macdonald	H. A. Hillman
Arkansas, Univ. of, Fayetteville, Ark.	L. G. Huggins	E. J. Anderson
Armour Inst. of Tech., Chicago, Ill.	L. E. Grube	H. M. Piety
Brooklyn Poly. Inst., Brooklyn, N. Y.	A. E. Shaw	H. B. Hanstein
Bucknell Univ., Lewisburg, Pa.	W. G. Gehring	M. P. Crandell
California Inst. of Tech., Pasadena, Cal.	O. R. Bulkley	L. J. Wells
California, Univ. of, Berkeley, Cal.	A. A. Emlen	F. C. Blockson
Carnegie Inst.of Tech., Pittsburg, Pa.	W. S. Andrews	W. J. Lyman
Case School of Applied Science, Cleveland, O.	M. S. Mead	A. S. Campbell
Cincinnati, Univ. of, Cinncinati, O.	W. F. Dunkl	C. B. Hoffmann
Clarkson Coll. of Tech., Potsdam,N.Y.	C. E. Tuiter	H. C. Allen
Clemson Agri. College, Clemson College, S. C.	J. R. Reardon	W. M. Clatworthy
Colorado State Agri. Coll., Ft. Collins, Colo.	Floyd Hall	W. M. Truesdell
Colorado, Univ. of, Boulder, Colo.	G. H. Dewey	R. H. Owen
Cooper Union, New York	G. E. Wilson	H. E. Thompson
Drexel Institute, Philadelphia, Pa.	D. Buchanan	R. E. Sidwell
Georgia School of Tech., Atlanta, Ga.	J. L. Torbett	F. R. McClellan
Iowa State College, Ames, Ia.	C. H. Hoper	G. L. Seaton
Iowa, Univ. of, Iowa City, Ia.	E. Paintin	P. F. Bowman
Kansas State College, Manhattan, Kans.	L. O. Sinderson	K. C. Frank
Kansas, Univ. of, Lawrence, Kans.	D. Eyer	Wm. Anderson
Kentucky, Univ. of, Lexington, Ky.	T. M. Riley	R. H. Craig
Lafayette College, Easton, Pa.	K. A. F. Pitt	L. Conover
Lehigh Univ., South Bethlehem, Pa.	E. H. Snyder	R. W. Barrell
Lewis Institute, Chicago, Ill.	E. Millison	C. P. Meek
Maine, Univ. of, Orono, Me.	C. R. Lappin	H. L. Durgin
Marquette University, Milwaukee, Wis.	G. E. Phelps	P. P. Stathas
Massachusetts Inst. of Tech., Cambridge, Mass.	E. J. Thimmie	H. D. McKinnon
Michigan Agri. Coll., East Lansing, Mich.	E. A. Pryce	J. G. Lauffer
Michigan, Univ. of, Ann Arbor, Mich.	R. N. Olds	A. J. Martin
Milwaukee, Engg. School of, Milwaukee, Wis.	M. J. Maiers	J. P. Gibbons
Minnesota, Univ. of, Minneapolis, Minn.	R. H. Olson	C. L. Sampson
Missouri, Univ. of, Columbia, Mo	M. P. Weinback	D. C. Jackson, Jr.
Montana State Coll., Bozeman,Mont.	R. R. Thomas	J. A. Thaler
Nebraska, Univ. of, Lincoln, Neb.	O. J. Ferguson	O. E. Edison
North Carolina State College, West Raleigh, N. C.	Z. M. Harry	P. M. Sullivan
North Carolina, Univ. of, Chapel Hill, N. C.	W. C. Moore	R. H. Jackson
North Dakota, Univ. of, University, N. D.	C. W. Randall	Byron Hill
Notre Dame, Univ. of, Notre Dame, Ind.	V. J. Brown	W. L. Shilts
Ohio Northern Univ., Ada, O.	D. J. Wolf	H. L. Vincent
Ohio State Univ., Columbus, O.	W. M. Kellogg	O. McGinnis
Oklahoma A. & M. Coll., Stillwater, Okla.	I. T. Knight	L. C. Minich
Oklahoma, Univ. of, Norman, Okla.	Cecil Roush	R. B. Greene
Oregon Agri. Coll., Corvallis, Ore.	J. H. Murton	J. H. Casto
Pennsylvania State College, State College, Pa.	H. T. Axford	D. N. Yoder
Pennsylvania, Univ. of, Philadelphia, Pa.	O. W. Manz, Jr.	A. R. Horner
Pittsburgh, Univ. of, Pittsburgh, Pa.	C. A. Anderson	A. F. Robert
Purdue Univ., Lafayette, Ind.	J. F. Welch	O. T. McIlvaine
Rensselaer Poly. Inst., Troy, N. Y.	W. J. Williams	L. S. Inskip
Rose Poly. Inst., Terre Haute, Ind.	F. M. Stone	C. B. Wilson
Rutgers College, New Brunswick, N. J	C. S. Beattie	E. H. Erickson
Southern California, Univ. of., Los Angeles, Cal.	R. H. Cockfield	E. B. Heath
Stanford Univ., Stanford University, Cal.	H. E. Becker	V. Marquis
Swarthmore Coll., Swarthmore, Pa.	J. C. Fretz	E. A. Green
Syracuse Univ., Syracuse, N. Y.	L. E. Angwin	L. E. Lawrence
Texas A. & M. Coll., College Station, Tex.	T. E. Keeton	R. S. Drake
Texas, Univ. of, Austin, Tex.	C. R. Granberry	C. H. Linder
Virginia Military Inst., Lexington, Va.	J. Giraud	J. E. Woodward
Virginia Poly. Inst., Blacksburg, Va.	T. F. Cofer	F. L. McClung
Virginia, Univ. of, University, Va.	T. R. Bunting	P. L. Weir
Washington, State Coll. of, Pullman, Wash.	C. R. Studer	E. J. Leahy
Washington Univ., St. Louis, Mo.	F. W. Schramm	E. H. Burgess
Washington, Univ. of, Seattle, Wash.	J. V. Wilson	A. W. Lundstrum
West Virginia Univ., Morgantown, W. Va.	H. Chandler	W. D. Stump
Wisconsin, Univ. of, Madison, Wis.	R. B. Bohman	J. W. Smart
Yale Univ., New Haven, Conn.	J. T. Houk	G. L. Artamonoff

Total 68

DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies.

Subway and Elevated Systems.—Bulletin 44018, 28 pp. The principal characteristics of several great rapid transit systems, from an electrical engineering viewpoint, are presented in this bulletin. The facilities for power production, transformation, transmission and utilization are outlined briefly for each of the systems in the cities of Boston, New York, Chicago and Philadelphia. General Electric Company, Schenectady, N. Y.

Electric Heating by Ironless Induction.—A reprint, 10 pp. of a paper by E. F. Northrup published in the "General Electric Review." Discusses the possibilities of heating by ironless induction. Ajax Electrothermic Corporation, Trenton, N. J.

Motors.—Circular. Describes type H. D. heavy-duty motors. The Louis Allis Company, Milwaukee, Wis.

Insulators.—Bulletin 1, Catalog 25.—Strain insulators for guy dead-end and anchor service. The Locke Insulator Corporation, Victor, N. Y.

Synchronous Motors.—"Synchronous Motors for Ammonia Compressor Drive." Booklet, illustrating the advantages of electrically driven ice plants and showing representative installations. Westinghouse Electric & Mfg. Company, East Pittsburgh.

Graphic Instruments.—Bulletin 1022. Describes improvements in chart-driving mechanism of latest instruments, and contains an article on "Graphic Instruments for Reporting Trouble." Bulletin 1112, "How to Make a Plant Survey," describes methods and results obtained through use of graphic instruments in industrial plants. Esterline & Angus, Indianapolis, Ind.

Electric Railway Transportation.—Bulletin 1655, 20 pp. Illustrates the actual operation and installation of the light weight double truck car, the safety car and the trolley bus. Describes the merits of each mode of transportation and the field of service to which each is best adapted. Westinghouse Electric & Manufacturing Company. East Pittsburgh.

Radio Receiving Products.—Bulletin, 8 pp. Describes the "Ducon" plug for insertion in lamp sockets; "Variadon" variable condenser; "Micadon" mica condenser; "Du-tec," a chemical rectifier to replace natural crystals. Dubilier Condenser & Radio Corporation, 48 West 4th Street, New York.

Electric Railway Equipment.—Helpful Hints On Its Maintenance. Bulletin 1656, 112 pp. The first edition of what is evidently intended to be an encyclopedia of operation and maintenance of equipment. Westinghouse Electric & Manufacturing Company, East Pittsburgh.

Air Compressors.—Bulletin. Describes a new line of vertical, belt-driven, air compressors, in which are incorporated such improvements as maintaining a constant level of oil in the crank case, and reliable regulation, which have not heretofore been applied to this degree in small vertical belt-driven machines. Ingersoll-Rand Company, 11 Broadway, New York.

Magnet Wire.—Bulletin. Reviews the process of manufacture and use of magnet wire. The Belden Manufacturing Company, 23rd Street and Western Avenue, Chicago.

Oiled Tubing.—Circular. For radio insulation and for the electrical insulating purposes in general. The Mica Insulator Company, 68 Church Street, New York.

Watthour Meters.—Bulletin 20. Describes "Semco", Model 1, watthour meters. Sewickley Electrical Mfg. Company, Sewickley, Pa.

Gate Valves.—Bulletin, 8 pp. Describes a new line of cast steel gate valves designed for 350 pounds working pressure at a total temperature not exceeding 800°; or 500 pounds working pressure at a total temperature below 100°. Reading Steel Casting Company, Inc., Bridgeport, Conn.

Outdoor Lighting Control.—"Engineer's Reference Book and Information Blank." 30 pp. Deals comprehensively with the remote control of all phases of outdoor lighting from the power house by means of the R-C-O-C System of Remote Control. Includes typical plans, data for solving problems connected with control of constant current transformers, multiple or series white-way system, traffic, subway, bridge, sign lights, and a wide variety of other applications to suit local conditions. South Bend Current Controller Co., South Bend, Ind.

College Laboratory Apparatus.—A new publication on laboratory apparatus for use in educational institutions. Such apparatus includes generators, phase advancers, synchronous converters, motors, oscillographs, transformers, arc welding sets, meters of all kinds, turbines, switchboards, etc. In general the laboratory apparatus has the same appearance, the same construction and the same electrical characteristics as the larger standard apparatus. The only points of difference are the size and arrangement of terminals and taps, which through attachment to panels or some other means, are made easily accessible. This specially designed machinery, therefore, has all the desirable features of commercial apparatus with none of its drawbacks in laboratory use. Westinghouse Electric & Mfg. Company, East Pittsburgh.

NOTES OF THE INDUSTRY

Monitor Controller Company, Baltimore.—Manufacturers of a button system of automatic control for motor driven apparatus, have recently established a branch office at 1100 Elm Street, Birmingham, Ala., with William H. Neville in charge.

Gibb Instrument Company, Bay City, Mich., has taken over under exclusive license, the manufacture and sale of the automatic and semi-automatic electric arc welding machines developed and heretofore manufactured by the Fred Pabst Company, Milwaukee, under their various letters patent and has contracted to act as selling agents for the Pabst line of patented covered electrodes.

Frederick Welles Prince, a member of the Publicity Department of the Western Electric Company, died suddenly at Detroit, on November 22, at the age of forty years. Mr. Prince was well known in the electrical industry through his connection with the Hartford Light and Power Company, the Westinghouse Lamp Company, and more recently with the Western Electric Company.

Line Material Company, South Milwaukee, Wis., held its annual sales convention December 17 to 22, at the Hotel Martin, Milwaukee. Mr. C. P. Wagner of the Minneapolis General Electric Company gave an interesting talk on Secondary and Sectionalizing Fuses and their use by his company. Arthur J. Sweet, consulting illuminating engineer and an officer of Traficon, Inc., lectured on Street Traffic Control and Regulation. Mr. Dan Wescott, President of the South Bend Current Controller Company, demonstrated R-C-O-C Switches. Those in attendance were Mr. W. D. Kyle, President of the Line Material Company, L. E. Hendee, Sales Manager, J. D. Hoit, Albany, N. Y., J. J. Desmond, Chicago, K. W. Kline, Kansas City, D. H. Millar, Des Moines, Ia., A. L. Dunmire, Oakland, Cal., I. W. Bolton, Milwaukee, L. A. Priester, Dallas, Tex., C. A. Moore, Charlotte, N. C., L. A. Greff, New York, H. E. Miller, Philadelphia, P. L. Reeves, Boston, E. R. McCoy, Indianapolis, P. O'Moore, Pittsburgh, E. W. Merriam, Hartford, Conn., F. T. Otis, Richmond, Va., F. T. Buckley, Little Rock, Ark., P. R. Gossman, Dubuque, Iowa.